DEVELOPMENT MONITORING PROGRAM
FOR
OIL SHALE TRACT C-b

C-b SHALE OIL PROJECT

Occidental Oil Shale, Inc., Operator

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February 23, 1979

U.S. DEPARTMENT OF THE INTERIOR PROTOTYPE

OIL SHALE LEASING PROGRAM

DEVELOPMENT MONITORING PROGRAM FOR OIL SHALE TRACT C-b

February 23, 1979

Submitted to:

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PREFACE

The first report on environmental monitoring at Tract C-b entitled Environmental Monitoring Programs for Oil Shale Tract C-b (Oct 1, 1976) supported the Detailed Development Plan (1976). It contained the monitoring programs for the Environmental Baseline Program from November 1974 through October 1976. Interim monitoring requirements from November 1976 through February 1978 were covered through correspondence with the Area Oil Shale Office. This present report on Development Monitoring Programs supports Chapter VI of Modifications to Detailed Development Plan (1977) and covers the period from February 1978 through the development phase. This monitoring program is adaptive and subject to change as new monitoring results are obtained. Any changes will be made with the concurrence of the Area Oil Shale Office.

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1.0 INTRODUCTION

1.1 Background

Section 1 (C) of the Lease Stipulations of the U. S. Department of the Interior Prototype Oil Shale Leasing Program requires the Lessee to conduct environmental baseline programs for two consecutive years and thereafter to conduct environmental monitoring programs to measure perceptible changes from the baseline conditions. This present environmental monitoring phase which is the subject of this report is called Development Monitoring.

The baseline has now been completed and results have been summarized in a five volume set plus Executive Summary: Tract C-b Environmental Baseline Program, November '74 - October '76, Final Report, (1977). An earlier version of this environmental monitoring report supporting surface retorting entitled Environmental Monitoring Programs for Oil Shale Tract C-b was issued on October 1, 1976. This document supported Chapter VI of the Detailed Development Plan, (1976). The present report supports Chapter VI of Modifications to Detailed Development Plan, (1977) for in-situ retorting, the present selected retorting scheme.

The purposes or objectives of environmental monitoring as defined in Section 1 (C) of the Stipulations are to provide: 1) a record of changes from conditions existing prior to development operations, as established by the collection of baseline data; 2) a continuing check on compliance with the provisions of the Lease and Stipulations, and all applicable Federal, State and local environmental-protection and pollution control requirements; 3) timely notice of detrimental effects and conditions requiring correction; and 4) a factual basis for revision or amendment of the Stipulations.

The achievement of these objectives for Development Monitoring requires that monitoring of designated environmental parameters be conducted beginning six months prior to the commencement of development operations and until the termination of operations, or until the Area Oil Shale Supervisor determines, to his satisfaction, that environmental conditions consistent with the requirements of applicable statutes and regulations have been established.

The Development Monitoring Programs will compare data obtained during the baseline period with information developed during subsequent operations in order to identify significant and meaningful trends and changes. It must be recognized that there may be considerable difficulty in determining the cause of an observed change from baseline conditions because of the many variables which can cause such changes. Most biological systems fluctuate around some mean value in response to environmental pressures, and observed departures from baseline conditions may reflect this inherent fluctuation. While a two-year baseline provides gross values for measured conditions, normal yearly fluctuations may vary significantly from mean values obtained during one specific two-year period. The Development Monitoring Programs for Tract C-b are designed to take these fluctuations into account and allow statistical comparisons of observed trends with baseline data and of development plots with control plots. Inherent in this is the necessity of consistency with the techniques used in the Baseline Programs.

All of the proposed Development Monitoring Programs are flexible within guidelines provided by the Area Oil Shale Office (AOSO) and are subject to periodic review and modification with the approval of the AOSO. In accordance with stipulations all monitoring results will be included in semi-annual data reports and an annual analysis summary report to the AOSO. It is essential that this program be dynamic and have sufficient flexibility to allow incorporation of new techniques as the program progresses, and to eliminate superfluous data collection methods if such methods become identified during conduct of the Development Monitoring Program. The annual summary report and quarterly review meetings with the AOSO provide mechanisms for achieving this objective. Furthermore it is recognized that a monitoring program must relate to project development phases.

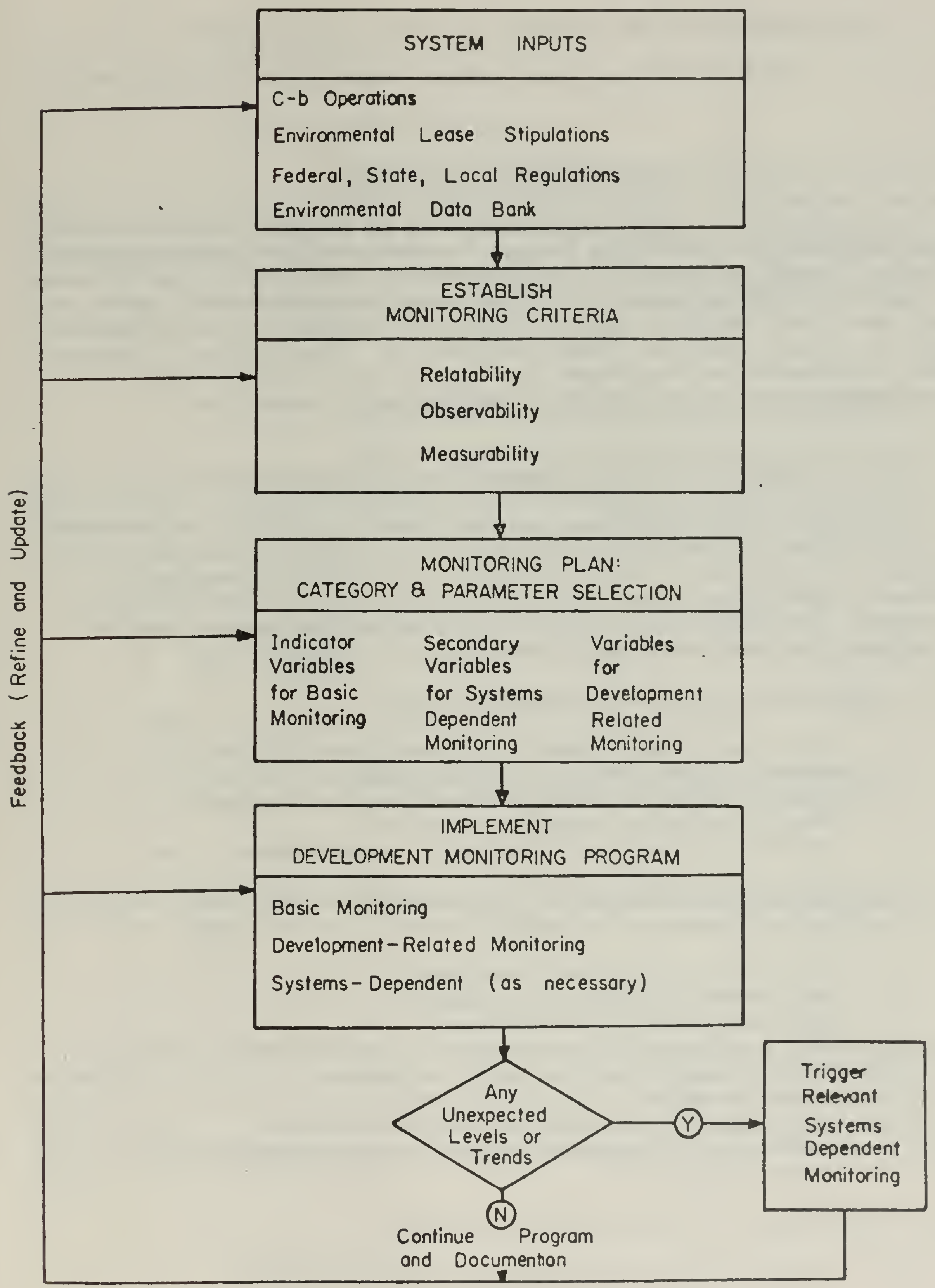
This report not only presents the subject programs for hydrology, air quality, meteorology, noise, and biology, but also recognizes ecosystem interrelationships which have particularly been brought into focus during the Baseline. Two new monitoring categories will now be monitored under this plan: subsidence monitoring and health and safety. This plan discusses systems and statistical techniques to be used to interpret trends and analyze monitoring data.

1.2 Conceptual Approach to Development Monitoring

Basically, over two years of planning have been incorporated into this Development Monitoring Plan. That is, the project has the benefit of two years of experience gained from the Environmental Baseline Program. Each of Volumes 2 through 5 (Hydrology, Air Quality, Ecology, and Ecosystem Interrelationships, respectively) of the Final Baseline Report contain a Utilization chapter which discusses planning inputs to Development Monitoring. These are incorporated into the related chapters of this document. Volume 5 is of special assistance in providing a conceptual framework for planning and is discussed below.

This approach utilizes the simple, multi-component, conceptual model shown on Fig. 1.2-1. The "outputs" or actions constitute the Development Monitoring Plan and its implementation (findings) as a result of monitoring. "Inputs" consist of the environmental baseline data bank, the environmental lease stipulations, the details of tract operation, and applicable local, state, and federal regulations. The mid-components or "decision matrix" consist of the three major criteria to which candidate variables for monitoring are subjected and the selected indicator variables in the Program. A final feature of this conceptual model is its feedback capability. Feedback from the program results to date to obtain new inputs ensures continual review and refinement of the monitoring programs as additional information is collected and analyzed. This is a provision not only for the evolution of the monitoring program in terms of methods used in collecting and analyzing data and for refining sampling frequencies and locations, but also a provision for factoring in the phases of development and their subsequent effects on the system.

Figure 1.2-1 CONCEPTUAL APPROACH TO DEVELOPMENT MONITORING



1.2.1 System Inputs

Each of the four input category subdivisions is discussed in turn:

1.2.1.1 <u>The Environmental Data Bank</u>

This input subdivision is composed of the data and analyses conducted as part of the two-year environmental baseline program on Tract C-b. The data contained in the Environmental Data Bank are in the areas of air quality and meteorology, surface and ground water hydrology, soils, geology, terrestrial ecology, aquatic ecology, re-vegetation and reclamation, archaeology, visual resources, noise, and land use. The data bank is the main source of information on the present condition of the Tract C-b system and for the interactions between the ecosystem components on the tract.

1.2.1.2 <u>The Environmental Lease Stipulations</u>

This input subdivision is composed of the Environmental Stipulations appended to the Oil Shale Lease and associated Conditions of Approval for Tract C-b. They are entered into the model directly as requirements, open to revision through proper procedures if such actions are appropriately indicated by the scientific findings of the two-year program. These stipulations that affect monitoring are listed below.

1) Stipulations fulfilled by Baseline studies.

   a. Collection of environmental data which were designed to determine conditions prior to development.
   b. Cultural investigations and identification of objects of historic value and scientific interest.
   c. Consideration and identification of scenic values.

2) Stipulations fulfilled by Preliminary Detailed Development Plan (DDP), Exploration Plan, and Revised DDP.

   a. Access and service plans development.
   b. Fire prevention and control plans.
   c. Health and safety considerations.
   d. Spill contingency plans and disposition of hazardous materials.
   e. Control plans for air and water pollutants.
   f. Control of noise.
   g. Waste materials disposal and water impoundments.
   h. Clearing and stripping of vegetation and consideration of timber resource.

3) Stipulations fulfilled by other Documents.

   a. Fish and wildlife management and mitigation plans.

b. Rehabilitation plans for soils and vegetation, including erosion control.

1.2.1.3 C-b Operations

This input subdivision contains all the specific details of tract development activities as depicted in the Detailed Development Plan and its modifications that influence monitoring of the physical and biological system. It is an area of concern that will be dynamic over time due to shifts in the kinds of activities as development proceeds. Major types of activities that will be reflected in the monitoring program are presented in Volume 5 of the Final Baseline Report (1977).

1.2.1.4 Local, State, and Federal Rules and Regulations

This input subdivision contains any rules and regulations that might pertain to Tract C-b, other than those contained in the Environmental Lease Stipulations or in Conditions of Approval originating from the AOSO. Examples of such rules and regulations are listed below:

1) Local Regulations

   a. Consideration of land use plans and zoning laws.
   b. Consideration of local, existing land uses, such as ranching and recreation.

2) State Laws and Regulations

   a. Compliance with state pollution and streamflow standards.
   b. Compliance with state mined-land-reclamation regulations.

3) Federal Regulations

   a. Compliance with federal air and water pollution standards.
   b. Compliance with federal regulations governing reclamation of lands.

1.2.2 Selection of Monitoring Parameters

The portion of the conceptual model used to select monitoring parameters consists of two parts: first, suitable criteria for selecting the indicator variables for Development Monitoring and second, the selection process itself. Indicator variables or species are those abiotic and biotic variables judged by the Lessee and the AOSO to best indicate the "state" of the system.

1.2.2.1 Selection Criteria

1) Relatability to Oil Shale Development

Variables deemed as relatable to oil shale development are those that:

a. are affected by and respond to the kinds of perturbations that result from the development of the operations scheduled for Tract C-b;
b. are those in which a change provides information relative to sensitive, important, and significant environmental features;
c. are those that are required by the Environmental Lease Stipulations.

2) Observability in the System

Variables that are observable are those that:

a. are key indicators of environmental change in the Tract C-b system, and as such provide early warning of these potential changes;
b. are important components of the system that are likely to be subject to any perturbations (e.g., sensitive consumer populations such as mule deer) relating to animal growth, number and movements.

3) Measurable

Variables that meet the criterion of measurability are those that:

a. can be measured without undue expense or effort (i.e., they are "cost-effective") and that are amenable to reproducible observation by different investigators;
b. are amenable to statistical testing so that significant differences between samples can be adequately determined--or--are of the go/no-go variety so that statistical interpretations are not necessary in determining significant differences between samples;
c. are those for which the differences between oil shale perturbations and naturally occurring trends can be determined;
d. are those that are comparable across disciplines, so that one given variable supplies information relative to the behavior of another variable.

1.2.2.2 Indicator Variables

The "candidate" variables that "pass" all the above criteria of relatability, observability, and measurability and are consistent with input constraints as required by Lease Stipulations, applicable Regulations, and permit terms are those selected as indicator variables for

Development Monitoring. The already-screened list of indicator variables is presented in Chapter 4, along with their role in impact assessment and mitigation. Subsequent chapters discuss each variable and its analysis mode.

1.2.3 Monitoring Categories

This section of the conceptual model consists of two parts: selection of monitoring types or categories and implementation of the Development Monitoring program into the appropriate categories. Such implementation involves "feedback" by virtue of its dynamic nature.

1.2.3.1 Types of Monitoring

1) Basic Monitoring

Variables placed in the basic monitoring category are those that meet each of the above three major criteria. These variables are destined for long term monitoring in order to maintain information regarding trends in the system. These variables will be monitored in order to establish an early warning system of potential system change through the development of the oil shale resource on Tract C-b.

2) Systems Dependent Monitoring

Unexpected trends in an indicator variable may occur either over time or between control and development stations (or plots). For example, suppose the deer population on the development area declines, but the control area's deer population remains the same as baseline numbers. In this case the reduced deer population probably is not due to yearly fluctuations but tract activity, and may require habitat improvements to produce more forage in the control area to compensate for the development area.

Another example is that unexpectedly high readings occur at a "downwind" air quality trailer over an extended period. Such values could "trigger" the need for an additional station. Thus the number of air quality stations necessary is "system dependent," i.e., dependent on the "state of the system."

If professional judgments are unclear as to the cause of a fluctuation, or a series of high readings warrant such action, a back-up study may be undertaken. This back-up study is referred to as Systems Dependent Monitoring. For each variable this program will be different, but in general the variable will be more frequently sampled, on a broader scale, perhaps with additional or (new) secondary variables and/or additional sampling sites. Therefore, in addition to a basic monitoring program definition, many key indicator variables may also have a systems dependent monitoring program. This is delineated on the tables of Chapter 4.

3) Variables Directly Related to Oil Shale Development

Variables entered into this monitoring category are those that are directly related to some phase of oil shale operations on Tract C-b. The majority of these programs are ephemeral; all are keyed to some specific action taking place on the tract.

1.2.3.2 Implementation of the Program

Basic monitoring involving the selected indicator variables is accomplished. Trends in these variables over time and between control and development plots will be analyzed by techniques indicated on the analyses matrices in Chapter 4. Unexpected results may "trigger" the systems dependent monitoring described above as part of a "feedback" process. Quality assurance techniques as discussed in Chapters 5 and 6 will assure sampling validity. Details of the Development Monitoring Plan are discussed in the chapters to follow.

2.0 TRACT DEVELOPMENT MILESTONES AND MAPS

2.1 Development Milestones

Schedule milestones are appropriate to cite inasmuch as they are a requisite to planning the Development Monitoring Program. These milestone dates are presented on Table 2.1-1 for the surface facilities shown on Fig. 2.1-1. The overall project guide schedule is presented on Fig. 2.1-2.

Shale tonnage during ancillary development and associated hoisting capacity during ancillary development are presented on Table 2.1-2.

2.2 Maps

Maps are useful to locate surface facilities, sampling sites and re-vegetation progress. Large scale maps (e.g., 1" = 1000') have been provided to the AOSO separately from this report, showing monitored stations in relation to development sites. The scale selected (purely for convenience) to show station locations for this report is approximately 1" = 4200+ feet. A base map to this scale is provided on Fig. 2.1-1.

2.2.1 Annual Raw Shale Pile Development

Maps depicting estimated shale-pile development are shown on Fig. 2.2-1 for development through the following years:

Fig. 2.2-1
- a. year 8
- b. year 17
- c. year 34
- d. year 40
- e. year 60

2.2.2 Monitoring Plan

A map depicting the composite of the Development Monitoring Plan station locations is provided as one of the large scale separate maps as discussed above. Station locations for each discipline are discussed and individual maps presented in their respective chapters. Station locations during the baseline monitoring period were depicted in the Final Environmental Baseline Report (1977).

TABLE 2.1-1

C-b SURFACE FACILITIES: MILESTONES

Site Preparation

11/77	Road Improvement, Site Preparation, Stream Crossing.

Ancillary Process Facilities

02/78	Start collar on 15' ventilation shaft.
04/78	Begin construction of permanent head frame for 15' shaft.
12/78	Begin sinking 15' ventilation shaft.
12/78	Complete head frame construction for 15' shaft.
10/80	Start collar on 10' temporary gas shaft.
10/80	Begin drilling 10' temporary gas shaft.
02/82	Complete 10' temporary gas shaft.
02/82	Complete 15' ventilation shaft.
03/82	Begin drifting off 15' shaft.
03/84	Kindle two-retort cluster.
12/84	Kindle four-retort cluster.

Ancillary Facilities

03/82	Begin construction of surface facilities.
03/82	Begin construction of underground facilities.

Mine Support Facilities

02/78	Start collars for 34' service shaft and 29' production shaft.
02/79	Begin sinking 34' service shaft and 29' production shaft.
03/82	Complete 29' production shaft.
03/82	Complete 34' service shaft.
05/83	Begin commercial retort mining.

Commercial (Full-Scale) Process Facilities

03/82	Start collar for 34' gas shaft.
06/82	Begin sinking 34' gas shaft.
07/84	Complete 34' gas shaft.
05/85-10/86	Construct commercial facilities.
12/86	Kindle first commercial cluster.

Reservoir Construction

04/79	Begin construction of dam.
06/80	Finish dam.

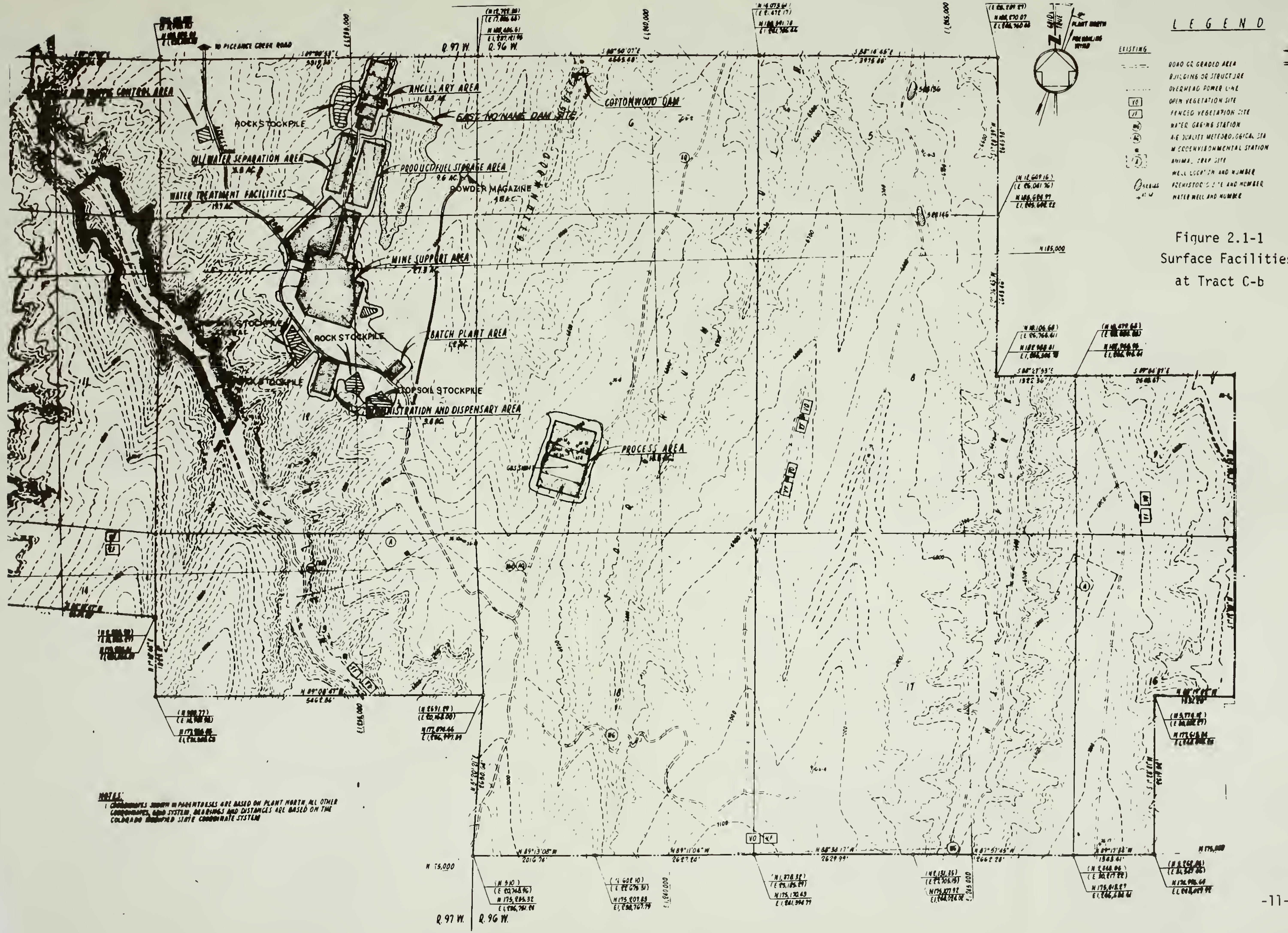


Figure 2.1-1
Surface Facilities
at Tract C-b

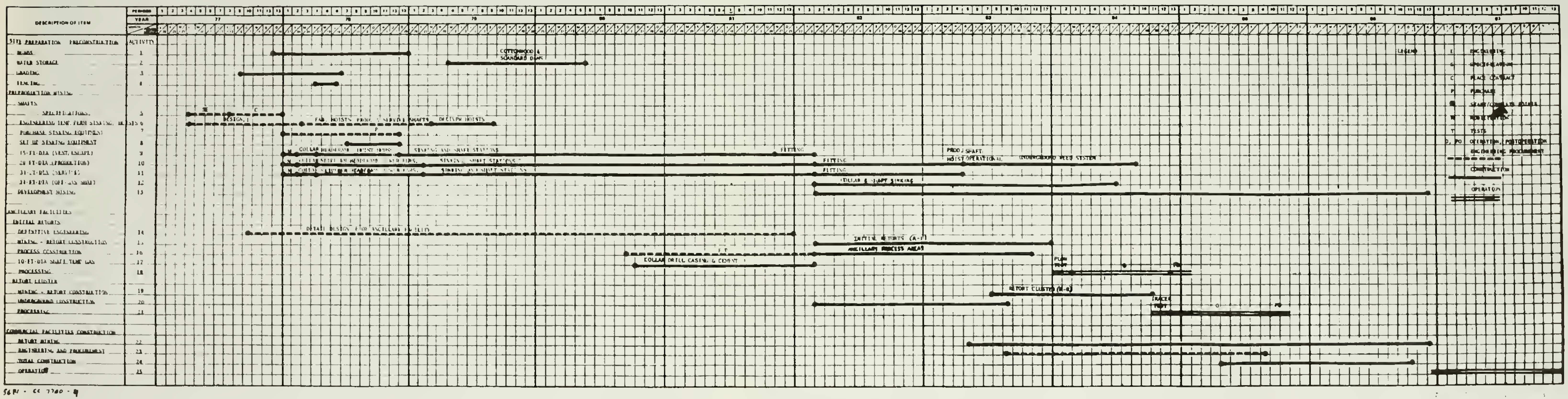


FIGURE 2.1-2
OVERALL PROJECT GUIDE SCHEDULE

TABLE 2.1-2

DAILY SHALE TONNAGE AND ASSOCIATED HOISTING CAPACITY

DURING ANCILLARY DEVELOPMENT

Average Tonnage During Construction Of The Shafts

10' - 40 Tons/Day up to 2/82.

15' - 75 Tons/Day up to 11/81.

34' - Service - 200 Tons/Day up to 3/82.

29' - Production - 200 Tons/Day up to 3/82.

Hoisting Capacity

3/82 - 8/84	5,400 Tons/Day
8/84	60,000 Tons/Day*

* Nominal shale mined is expected to be 45,000 - 50,000 Tons/Day

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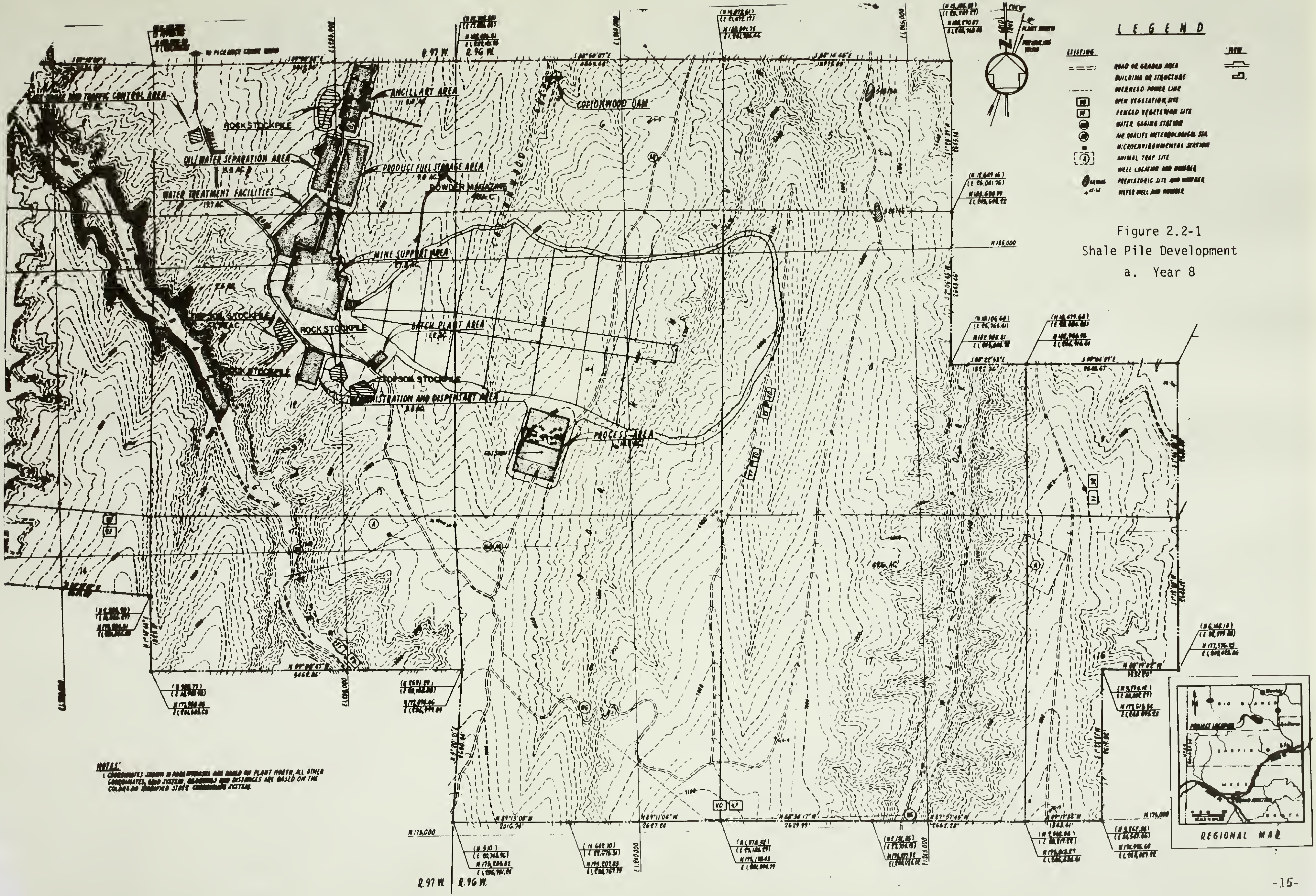

Figure 2.2-1
Shale Pile Development
a. Year 8

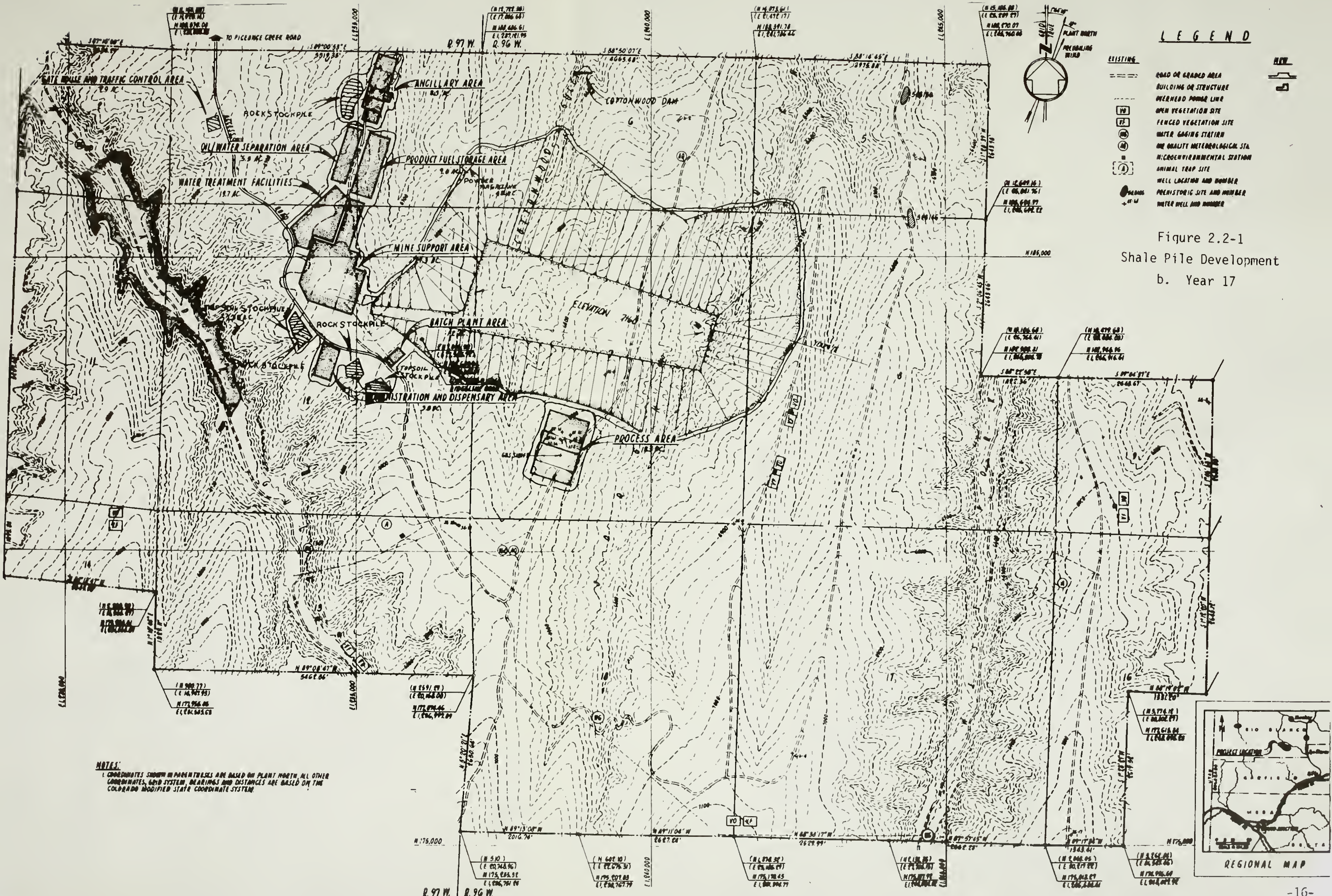

Figure 2.2-1
Shale Pile Development
b. Year 17

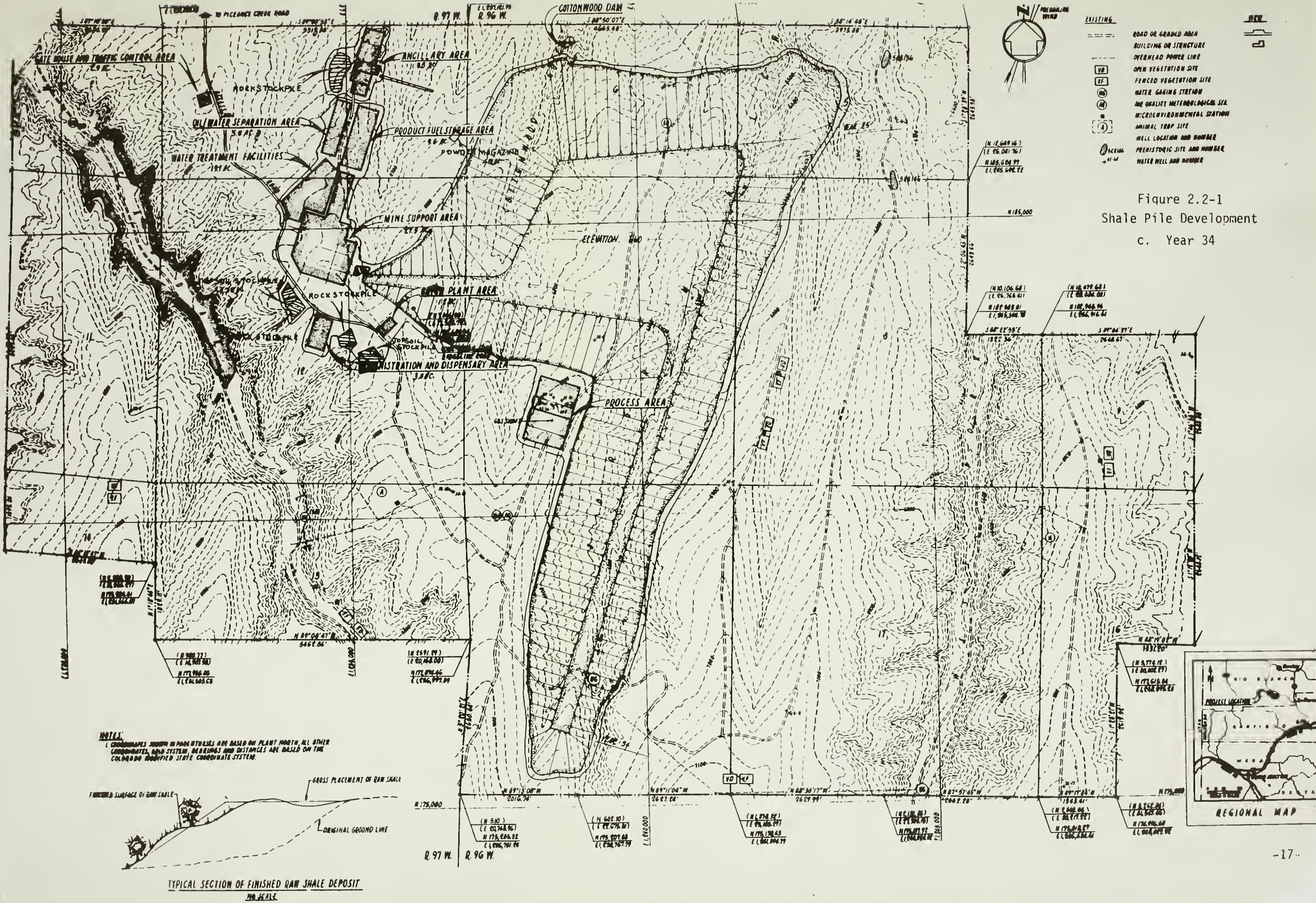

Figure 2.2-1
Shale Pile Development
c. Year 34

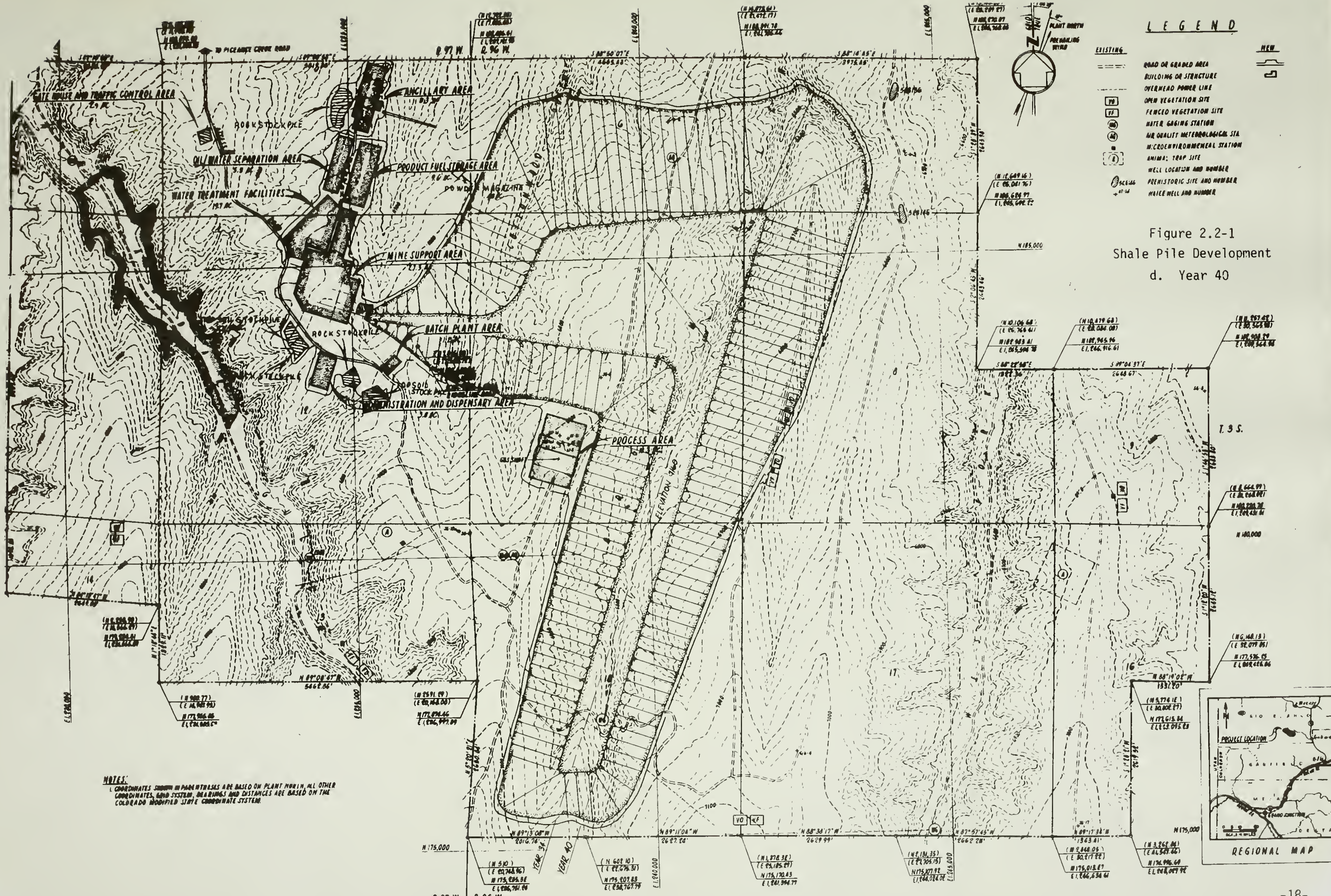

Figure 2.2-1
Shale Pile Development
d. Year 40

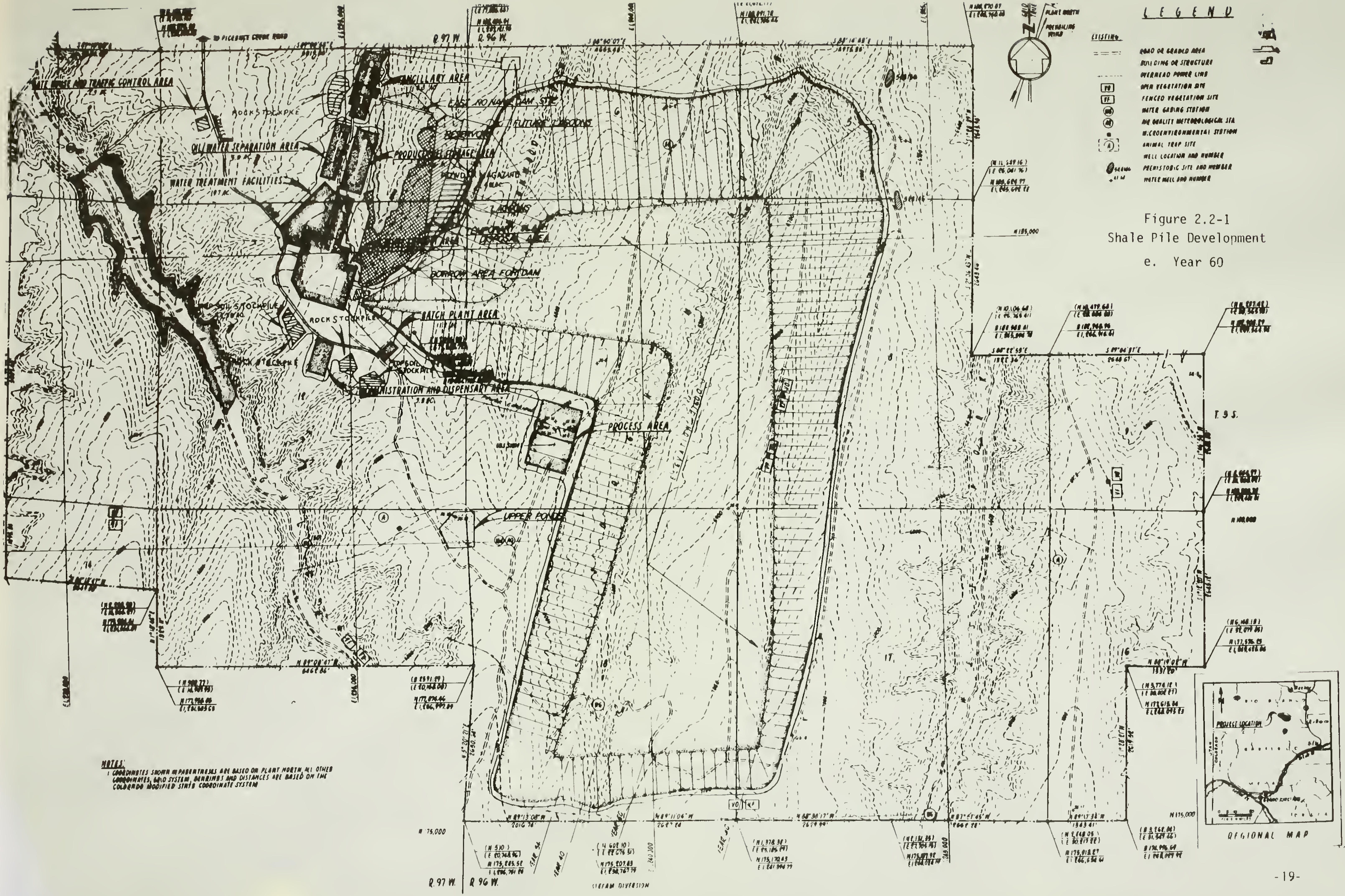

Figure 2.2-1
Shale Pile Development
e. Year 60

3.0 TRACT PHOTOGRAPHY

3.1 Surface Program

3.1.1 Purpose and Scope

Section 1 (C) of the Environmental Lease Stipulations requires that the Lessee conduct monitoring programs to measure perceptible changes from baseline conditions. Coverage from selected points of the C-b Tract will provide:

1) a record of changes from conditions existing prior to development operations;
2) visual evidence of successional changes in the ecosystem;
3) a visual record of surface disturbance;
4) an historic account of surface development; and
5) a visual basis for revision or amendment of the Stipulations.

3.1.2 Photo Map Points

Thirty-one points have been selected from which a 360° pan will be photographed on a yearly basis. (Fig. 3.1-1).

Additional points may be selected on an as-required basis. A 35mm camera with an f 1.8, 55mm lens using Ektachrome Professional Type R, ASA 64 film will be used.

3.1.3 Frequency of Monitoring

Once each year in June between 10am and 2pm on cloudless days a 360° photo pan will be taken from each of the 31 photo map stations.

3.1.4 Archiving

A complete set of the 35mm slides are numbered as to station, aspect and date. This set is stored in plastic envelopes and bound in a 3 ring binder, then filed in a unit designed to curtail dust and light as a part of the permanent record of the C-b Shale Oil Venture. This record shall include weather conditions, camera and film data, height of camera above ground, and direct or diffuse lighting identification.

3.2 Aerial Program

3.2.1 Purpose and Scope

The ojectives of aerial photographic coverage of the C-b Tract and a one mile buffer utilizing vertical viewing are to provide:

1) a record of changes from conditions existing prior to development operations, as established by the collection of baseline data;

2) timely notice of certain detrimental effects and conditions requiring correction;

3) general vegetative conditions (cross reference Section 8.7.4 under Biology for analysis discussion).

4) inventory of site physical conditions (cross reference Section 11.4.1 under subsidence).

5) subsidence details (Ref. Section 11.4.2).

3.2.2 Camera, Film and Flight Specifications

In items 1) to 4) above, the scale is 1:6000. Film is black and white, color and color/infrared. Resolution is such that an object 3' across on the horizontal plane can be seen with the unaided eye. Flight lines are flown from West to East and photography taken from 10am to 2pm on cloudless days. Side overlap of 40-50% and fore-and-aft overlap of 60% between photographs are to be specified. Aerial photographs will show visible ground control points as 3' x 12' white crosses on established section corners within the C-b Tract.

Item 5) will be given further definition at a future date.

3.2.3 Frequency of Monitoring

Vertical aerial photography is obtained on or about the 15th of June at a scale of 1:6000. Frequency is annually for black and white and color/infrared and once every five years for color.

3.2.4 Archiving

One set of color prints shall be used for construction of a mosaic, and one set of black and white, color, and color/infrared shall be stored in a unit designed to curtail dust and light as a part of the permanent record of the C-b Shale Oil Venture. The annual record shall include weather conditions, camera and film data, height of camera above ground and information on direct or diffuse lighting identification.

An uncontrolled color mosaic for the June 1974 flight is on display at Occidental's Grand Junction offices.

3.2.5 Methods

1) The next color mosaic obtained will be compared with June 1974 mosaic to identify major areas of change and a map indicating changes prepared.

2) Stereo pairs will be utilized to examine the most significant major changes in more detail. Results will be documented in the data and analysis reports.

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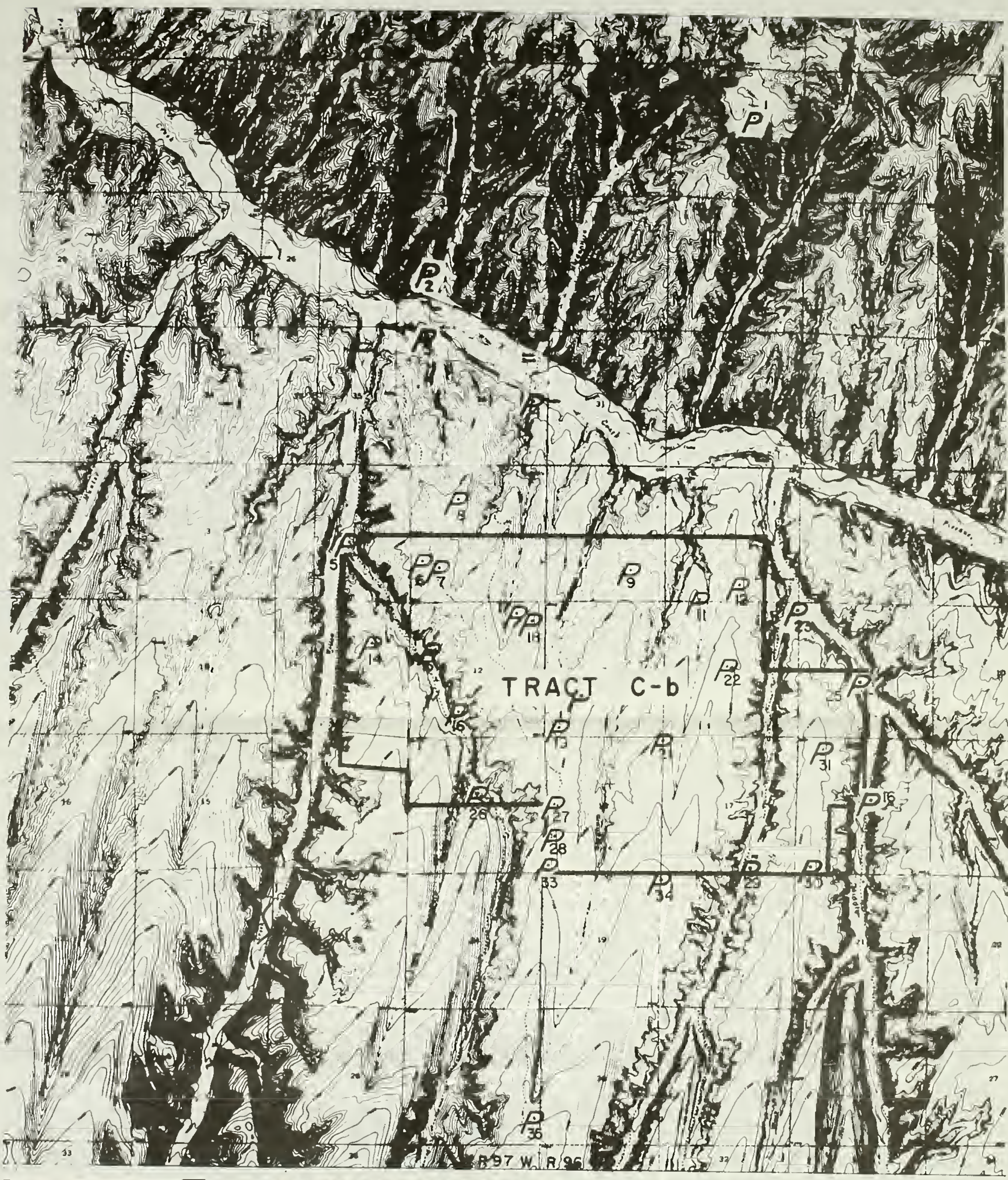
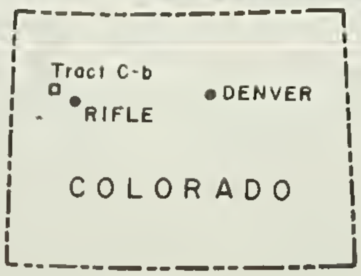


SURFACE PHOTOGRAPHY NETWORK



INDEX MAP

^{6}P = Photo Map Station

Figure 3.1-1

4.0 INDICATOR VARIABLES IN IMPACT ASSESSMENT AND MITIGATION

"Indicator" variables or indicator species are those variables which best indicate the "state" of the ecosystem. This "state" may vary from the relatively low background level obtained during Baseline to another level during development, e.g., low background ambient SO_2 to somewhat higher ambient SO_2 after the oil shale plant begins operations. These environmental variables are indicators of the ecosystem state in that they reflect change either as a direct or indirect result of perturbations introduced through oil shale development and/or processing operations. The importance of indicator variables is that they will be used as the means for achieving the objectives of the Development Monitoring Program stated in Section 1.0.

4.1 Identification

Table A-1 in Appendix A lists all the environmental variables that at the present time are used as indicator variables. The list may be increased or decreased as experience and future analyses indicate. A critical review of the value of each variable will be made annually as well as the need for additional variables.

4.2 Role of Indicator Variables in Impact Assessment and Mitigation

Table A-1 also includes: the oil shale development-produced perturbations that the indicator variables respond to; the environmental consequences; threshold or action levels to "trigger" either new secondary variables, sampling changes, and/or additional primary sampling sites; and an indication of the ways the variables are tied to the development plan and schedule, if any.

The indicator variables constitute the Basic Monitoring Category of Chapter 1. Secondary (additional) variables or increased sampling sites or frequency constitute elements referred to as the Systems Dependent Monitoring Category. It is to be expressly understood that secondary variables are not monitored except when threshold values for primary variables are reached. Some future "readjustment" of selected threshold levels may be necessary. If the primary variable level drops below the threshold level then monitoring of the secondary variables in the special studies conducted may terminate, but subject to prudent judgment. The entries in Table A-1 under development plan constitute the monitoring category called Development-Related Monitoring. These three categories are discussed in the monitoring chapters that follow.

Threshold or action level is defined as an arbitrary level selected on a case-by-case basis indicating some noticeable change has been measured above baseline values. At this threshold value secondary variables are "triggered" to be measured, increased primary variable sampling frequency is to occur, more primary variable sampling sites are to be utilized or combinations of the above are to be utilized.

Because the number of indicator variables in this program is very large and/or the sampling of some is infrequent enough that they do not lend themselves to time series plots, the following classes of variables are defined:

Class I variables are those indicator variables at selected representative stations which by virtue of the fact that they are sampled at least monthly are amenable to time series plots. (The rationale for this sub set is to reduce the large total number of variables plotted to a tractable number.)

Class II variables are indicator variables sampled less frequently than monthly.

It is recognized that selection of threshold levels is of considerable importance with potentially far-reaching consequences. General guidelines for their use are as follows:

1) One of the Quarterly Review Meetings with the AOSO will be devoted primarily to the examination of the trends in the Class I indicator variables and to the threshold values for all indicator variables.

2) Class I variables will be plotted as time series. The lessee will maintain and update these plots. These plots will be available for examination by project management and AOSO and reported in the semi-annual data reports.

3) The following statistics will be calculated and reported for the Class I variable monthly averages over the complete time period including baseline: Mean, standard error of mean, standard deviation, moving average, and test for slope. Where adequate data are available, a time series univariate forecast model may be developed and one year forecasts projected with confidence intervals.

4) Variables with significant trends toward threshold values, and variables that have peaks that have exceeded threshold values will be flagged for review with project management and with AOSO.

5) Environmental impact assessment of projected trends in the flagged indicator variables will be prepared. Recommended mitigating measures will be prepared along with an assessment of the impact of implementing these measures. These analyses will be presented to project management and to AOSO within the initiation quarter.

6) All analyses performed in the above procedures will be documented and made a part of the Annual Analysis Report.

7) Prudent judgment of the lessee in consent with the AOSO shall govern as to when changes shall be implemented with respect to monitoring plan and threshold levels of the indicator variables.

4.3 Data Analysis Matrices

The Developmental Monitoring Plan is organized by environmental discipline (e.g., Hydrology, Air Quality and Meteorology, Noise, and Biology). The Monitoring Plan for each of these disciplines describes studies designed to provide relevant data on indicator variables to be used to assess the impact of shale mine development and operations on the environment. The studies and analyses are discussed in subsequent chapters relating to each discipline.

Data analysis matrices have been developed to provide visibility for the plan to collect and analyze data relevant to the objectives for each study. The matrices are therefore organized by discipline, study, collection parameters, and analysis techniques to be used. The matrices are presented in the respective chapters for the discipline-detailed monitoring plan (Chapters 5 through 8).

A summary of the analytical techniques to be used is presented in Chapter 13. Typical tests and null hypotheses are stated.

Data collected during the baseline and interim monitoring period relating to most of the studies will be entered into and maintained in a computer data base. Analyses will utilize the computer to select the appropriate data and to execute the computerized statistical model in performing the analyses.

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5.0 HYDROLOGY

5.1 Introduction and Scope

There are two distinct aspects to monitoring the effects of oil shale development upon water resources. The first is water quality and the second is water quantity. Quality and quantity are, of course, interrelated to a certain extent, and may have synergistic effects in the biological sphere. However, from a practical standpoint it is useful to separate the two aspects in initially determining monitoring requirements; then some readjustments can be made for the sake of efficiency when combining the elements into a complete monitoring program.

Monitoring the quality of water resources is often thought of as merely sampling streams and wells. However, the purpose of a monitoring program is not merely to document environmental changes if and when they occur, but to provide a framework for predicting impacts related to such changes before they occur, to provide the data necessary for such predictions, and to determine the effectiveness of mitigating procedures. At the same time, more prosaic objectives of documenting compliance with legal standards for discharge, etc., must be satisfied. An effective monitoring program must take into account the geology and hydrology of the specific site, as well as the characteristics of the impact-producing development being monitored. The following sections will discuss the rationale for choosing monitoring sites, monitoring parameters, and monitoring frequency. An ultimate goal of the complete monitoring program is to observe and predict effects in the biotic realm due to any changes in water resource properties. This hydrological program is intended to provide data on quality and quantity which will be useful for this purpose as well as for the more usual water resource analyses, including the determination of effects on other water supplies off-tract, i.e., Piceance Creek and nearby springs and seeps.

Data obtained during the two-year Environmental Baseline Program will be utilized as (a) an accumulation of background data which in conjunction with the interim-monitoring data establish reference levels that will be used with environmental monitoring data to measure future changes; (b) an aid in designing the monitoring program to be followed during future development and operational phases of the project; and (c) to influence the nature of development plans and procedures.

The baseline program was designed to cover all parameters of possible importance without knowing in advance what the occurrence, concentration, and importance of those parameters might be. For example, water quality monitoring was instituted on ephemeral streams without knowledge of the flows. Because no significant flow has been observed on most of those streams during the baseline period, the data collected to date do not appear to justify a more extensive water quality monitoring at these sites. On the other hand, the baseline program has revealed certain deficiencies in earlier concepts of the tract hydrology and a need for additional data in some areas. An example of this is the two-aquifer concept surrounding the mining zone, originally the

assumption being that there were essentially two deep aquifers separated by the Mahogany Zone. Observation wells were completed in accordance with this concept. It is now known primarily from pump spinner tests conducted after Baseline that the geology and hydrology are much more complex and that highly stratified aquifers and aquitards more accurately characterize the aquifer system. This more complex aquifer-aquitard system is illustrated in Figure 5.1-1. For purposes of identification these new subdivisions of the previous upper and lower aquifer system are as follows:

1) UPC_1 - Upper Parachute Creek #1: Approximate limits extend from the Uinta Formation to the top of the 4 Senators zone.

2) UPC_2 - Upper Parachute Creek #2: Extends from the base of the 4 Senators Zone to the base of the A-Groove.

3) LPC_3 - Lower Parachute Creek #3: Extends from 30 feet below the base of the A-Groove to the top of the R-5 Zone.

4) LPC_4 - Lower Parachute Creek #4: Extends from the middle of the R-5 zone to the base of the L-4 Zone.

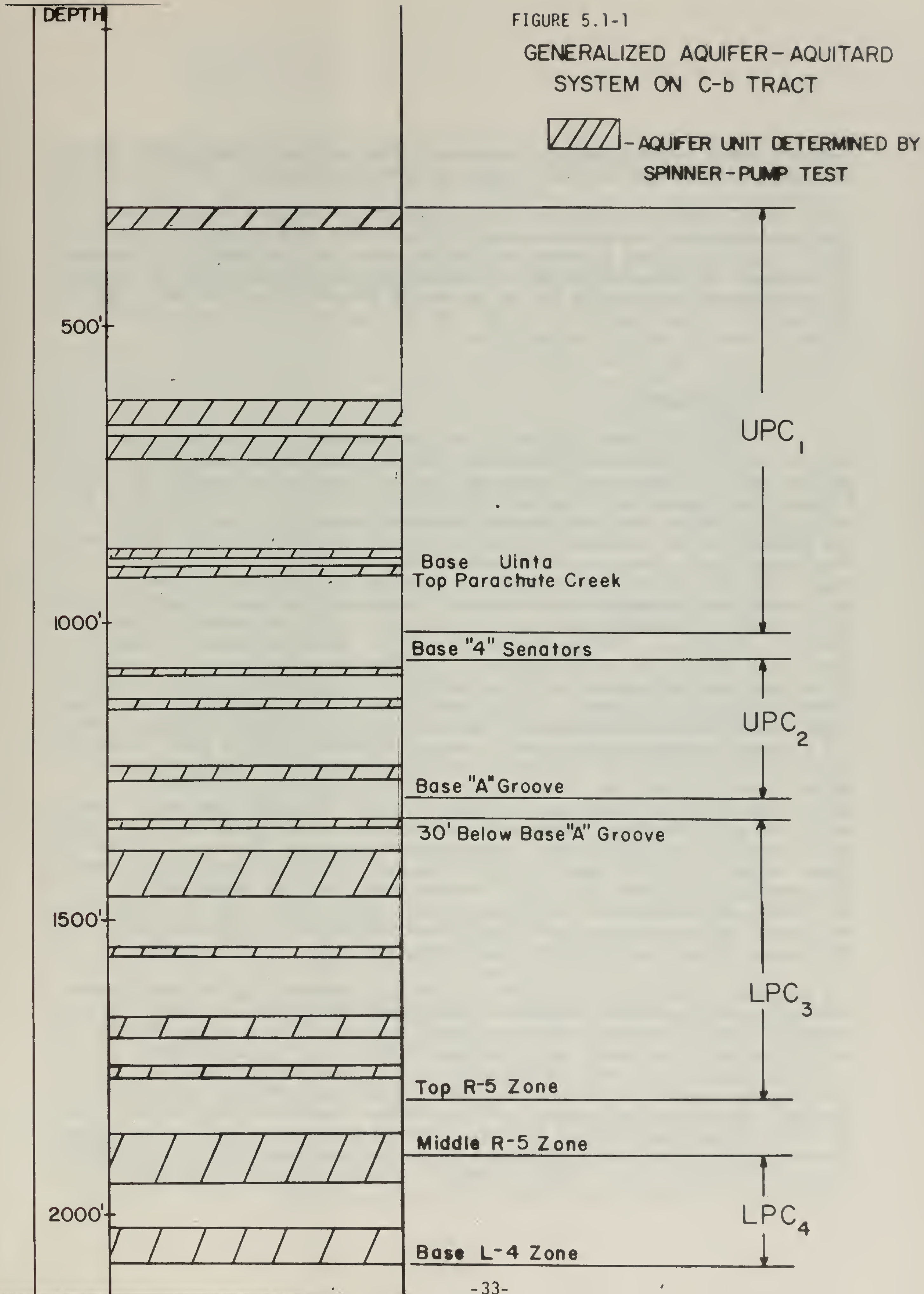
Water analyses obtained during the baseline period suggest that formation waters derived from the interval extending from the base of the 4 Senators Zone to the top of the R-5 zone are of comparable quality so that mixing can take place without affecting the potential use of these waters. The interval encompasses the UPC_2 and LPC_3 subdivisions of the aquifer system and includes water-bearing zones which will be subjected to dewatering during mining operations.

The hydrologic data required for a monitoring program and their spatial and temporal resolution depend on the setting and on the kinds of human impact being considered. Monitoring can be defined as the activity of making systematic observations of parameters related to a specific system with the object of providing information on the characteristics of the system and how and why these characteristics change with time. Some of the requirements of information from a monitoring network are to: (a) ascertain the current status of water quality required for planned management of water resources, (b) determine the extent of compliance (both natural and man-related) with water quality standards, (c) provide data which can be used to assess slow, long-term trends, as well as more transient hydrologic events, (d) determine the effectiveness of pollution control measures, (e) identify problems requiring corrective action before significant damage occurs, (f) provide input to the design of corrective or mitigative actions, and (g) determine the efficiency of such corrective actions.

Under the present development plans for C-b, the hydrologic monitoring program has been revised to cover the changing phases of development. The first phase covers the period from the completion of the interim monitoring period to the completion of shafts. The second phase covers the period of lateral drifting and mine dewatering to retort construction of the ancillary development. The third phase covers the period of ancillary retort ignition and

FIGURE 5.1-1

GENERALIZED AQUIFER-AQUITARD SYSTEM ON C-b TRACT



commercial mine construction and operation. The monitoring program has been designed to correspond to these phases of C-b development.

Lastly, built into this program is the monitoring of water produced during the retorting phase and post-retorting phases. This information will be used in quality control measures and incorporated into the continuing programs to determine the potential effects of spent retorts on the groundwater regime in the Piceance Basin and to aid in the design of mitigative actions. The C-b Venture is committed to protecting the groundwater of the State of Colorado from any possible degradation.

5.2 Surface Water

Changes in water quality or the modification of flow in any part of the hydrological sphere may ultimately have an effect on the quality of surface waters. Thus surface water quality is linked to groundwater quality. A properly designed monitoring program, however, will detect these effects propagating through the groundwater system long before the surface effects are seen and allow lead time for further monitoring and/or mitigative action. The discussion in this session is devoted only to those effects which may appear directly in the surface waters. Degradation of surface streams is most commonly attributed to point source discharges, for example, sewer outfalls, cooling system discharges, etc. In these cases, monitoring of the source is effective. For the C-b project direct discharges may only take place from surface reservoirs and only after the water is treated, if needed, to achieve acceptable water quality standards. The monitoring program is therefore designed to detect (1) unplanned point discharges, such as spills or leaks from trucks or pipelines, (2) effluents from non-point discharges, and (3) planned discharges from retention dams. Accidental spills would likely cause intensive short-term pollution and not be detected in the stream by periodic routine sampling. Such spills will be detected by continuous monitoring, reported, and special samples would be taken as necessary. The major emphasis in surface water monitoring will be on non-point source pollution and direct discharges from storage reservoirs. Sources of these types include: (1) increased erosion rates and stream sediment loads due to construction activities, (2) runoff from process plant and paved areas, (3) runoff carrying solids resulting from air-borne particulate or gaseous emissions, (4) seepage or runoff from piled materials, and (5) infiltration into the groundwater system from reservoirs, ponds, or injection wells.

The location of monitoring stations for surface water quality is a relatively straightforward procedure when only a small drainage area is involved. A sampling station on each tributary of significance will make it possible to quickly pinpoint the source of any changes detected in the mainstream. If larger drainage areas were involved, then a rationale must be developed for placing the monitoring stations in specific locations. For the C-b tract, however, the surface hydrology is defined rather simply in terms of the mainstream Piceance Creek and its two perennial tributaries, Willow Creek and Stewart Gulch. These three stream elements completely encompass the surface drainage from the tract. Smaller ephemeral tributaries drain much of the tract where construction activities will be concentrated.

The four major gauging stations which presently monitor Piceance Creek, upstream and downstream of the tract, as well as Willow Creek and the stream draining Stewart Gulch will therefore be retained as part of the environmental monitoring system. Although significant flows on ephemeral streams occur infrequently, high flows of short duration were recorded in 1977 and are likely to recur in the future. Monitoring of these tributaries will therefore continue, as will sampling of springs and seeps for water quality. Such samples are useful in determining the source of any variations in surface water quality.

Selection of water quality parameters to be monitored should be based in part on the composition of possible pollutants and on observed quality changes and will focus on specific constituents chosen because of their hazardous character, persistence, concentration, ease of identification, or other pertinent characteristics. It is felt that the major probability for direct surface water degradation is increased erosion and sediment loads resulting from construction activities. Thus special attention will be given to maintaining sediment records at all stations. In addition to suspended sediment, total dissolved solids and turbidity are important parameters to be monitored. These three measurements are sufficient to record a major change in streamload resulting from increased erosion or runoff from piled solids. To determine the nature and source of the solids and their effect on stream biology, such standard measures as temperature, dissolved oxygen, pH, hardness, alkalinity, and major ion concentrations will also be determined on a routine basis.

Detection of spills and leaks of oil and other organic materials would be accomplished by normal analyses for oil and grease, and for dissolved and suspended organic carbon. Pollution via runoff from paved areas may be detected in these analyses. Fractionation of the dissolved organic carbon will be used to identify classes or origins of pollutants.

Analyses for trace elements will be designed in accordance with possible sources which can be defined. From examination of the geochemical and hydrological characteristics of the C-b resource, it is apparent that the elements fluorine and boron are of special significance. Fluoride ions are naturally present in high concentrations in all deep aquifers underlying Tract C-b. Thus any surface water changes resulting from mine-flow water reaching the surface via leakage from well injection systems, holding reservoirs, or sprinkler irrigation systems should be apparent as an increase in fluoride levels. The concentration of fluoride is not readily altered by naturally-occurring groundwater phenomena. There is such strong contrast between surface and deep aquifer waters with regard to this element that no other identification of the source of change would be necessary in most cases. Boron is naturally present in the deep aquifers also. The concentration of boron must be reduced to acceptable levels before the water can be impounded and discharged or sprinkled. Another category of trace contaminents which is of concern is polynuclear aromatics (PNA). The nature of occurrence of these compounds in natural waters is not well understood so that some research is necessary. Particular compound analyses and scheduling will be coordinated with the AOSO.

5.2.1 USGS Gauging Stations

5.2.1.1 Objectives and Rationale

Surface water gauging stations were constructed through a contract arrangement with the United States Geological Survey and the Colorado River Water Conservation District. The USGS Water Resources Division Sub-District office in Meeker, Colorado is responsible for operation and maintenance of the stations under this contract. A total of 13 stations were installed on and near the Tract. Nine of the stations are located on ephemeral or intermittent streams. The other four are located on perennial drainages and are considered major gauging stations. (Refer to Figure 5.2-1). These stations were operated during the baseline period and will be operated through the Ancillary Development phase at C-b, subject to annual re-evaluation of each station over the next five years. The principal objective for this surface water program was to establish an environmental baseline for the stations over the first two years of operation. During Development Monitoring these stations will be used to observe possible water quality changes from surface runoff.

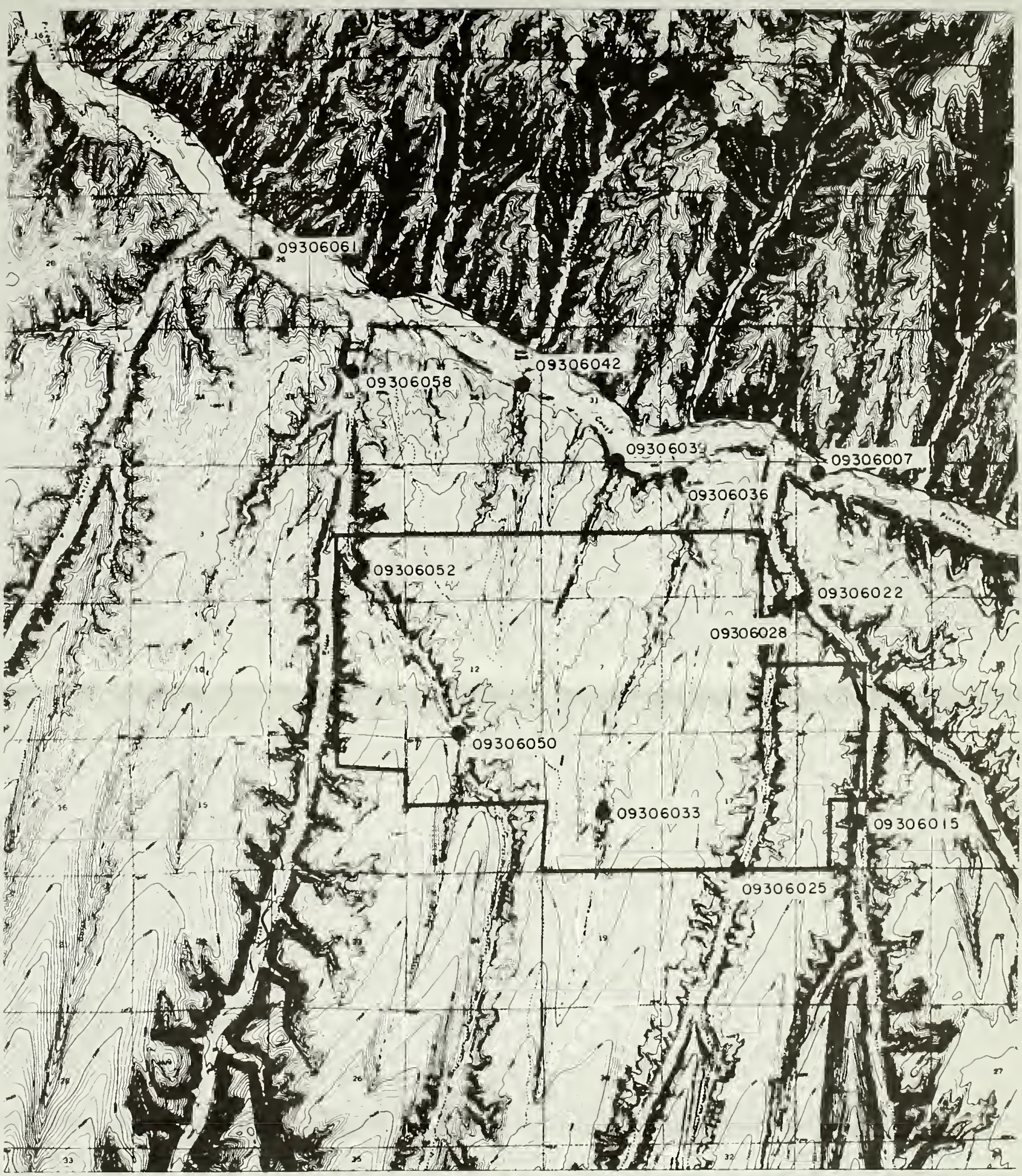
5.2.1.2 Experimental Design and Data Analysis

The monitoring network will be conceptually the same as that used during the baseline period. However, the monitoring of ephemeral streams may be subject to diminuition while increases may be made in the number of upper- and deep-aquifer monitoring wells. A summary of the various components of the monitoring network follows.

Figure 5.2-1 is a map of the Tract showing the location of the surface water monitoring stations which would be included in the environmental monitoring program. The monitoring program will utilize the existing stations which are included in the baseline program.

Cottonwood Gulch, which will drain storm run-off from surface facilities, ore storage piles, roads and other construction areas, will be monitored by station #09306039. Station #09306042 in the unnamed gulch west of Cottonwood will monitor the effects of road and shaft construction in that area and station #09306036 at the mouth of Sorghum Gulch will monitor construction activities which may take place there in conjunction with its upstream location #0906033. These three gulches are dry gulches containing only intermittent flow resulting from snow and storm runoff. Pollution of this water will be avoided or reduced by the policies included in the Oil and Hazardous Materials Spill Contingency Plan and the Erosion Control and Rehabilitation Plan.

Stewart Gulch and Willow Creek will probably not be affected by major construction and operation activities. These tributaries will continue to be monitored by stations #09306022 and #09306058. Stations #09306025 in the upper West Fork Stewart and #09306015 in Middle Fork Stewart will be operated as in baseline.



U.S.G.S. STREAM GAUGING STATION MONITORING NETWORK

Figure 5.2-1

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Piceance Creek will be monitored by existing stations #09306007 and #09306061, upstream and downstream of Tract C-b, respectively.

Existing station #09306052 at the mouth of Scandard Gulch and station #09306050 located near the southern tract boundary on Scandard Gulch will be operated as usual.

Each of the foregoing stations will be operated during the Ancillary phase of Development. After plant operations have been in effect for some time and monitoring conditions are stable, sampling parameters and schedules for all stations will be reviewed and modified as appropriate after approval by the AOSO.

In summary, the following stations constitute the surface water monitoring program:

USGS NO.	STATION LOCATION	COMMENTS
09306007 - MAJOR	Piceance Creek below Rio Blanco	operate during life of project
09306061 - MAJOR	Piceance Creek at Hunter Creek	operate during life of project
09306042	Unnamed Gulch west of Cottonwood Gulch	used to monitor road construction activities, and mine area development; reevaluate at a later date
09306036	Sorghum Gulch at mouth	operate during life of project
09306033	Sorghum Gulch upstream	operate during ancillary, reevaluate at a later date
09306039	Cottonwood Gulch at mouth	operate during life of project
09306022 - MAJOR	Stewart Gulch	consider reduction if data are stable after period of commercial operations
09306052	Scandard Gulch at mouth	operate during life of operation
09306058 - MAJOR	Willow Creek	consider reduction if data are stable after period of commercial operations
09306050	Scandard Gulch upstream	operate during ancillary development, reevaluate at a later date
09306028	West Fork Stewart mouth	operate during ancillary development, reevaluate at later date

USGS NO. - Cont'd	STATION LOCATION	COMMENTS
09306025	West Fork Stewart upstream	operate during ancillary development, reevaluate at later date
09306015	Middle Fork Stewart Gulch	operate during ancillary development, reevaluate at later date
09306033	Sorghum Gulch upstream	operate during ancillary development, reevaluate at later date

During development and construction, the monitoring stations will be sampled according to the schedule and parameters listed in Table 5.2-1 (Coordination with biological aquatic sampling will be maintained as required). As indicated above, both schedules and parameters will be reviewed for possible modification annually.

In addition to the laboratory analyses listed in Table 5.2-1, continuous measurements of flow, temperature and specific conductance will be made at all stations. At the four major stations (on perennial streams) pH and dissolved oxygen will also be measured continuously and turbidity will be recorded continuously at the two Piceance Creek stations. Continuous sediments samples are obtained at Stations 007, 022, 039, 058 and 061. All water quality samples will be analyzed by procedures previously used during the Environmental Baseline Study. All analysis and data verification are performed by the USGS labs in Denver and by the USGS Subdivision office in Meeker. Sediment characterization will be accomplished annually at Stations 061, 007, and 042. If anomalous conditions are suggested by data from these stations, measurements will also be made at Stations 052, 039, 036, and 028.

Data analysis for hydrology is summarized in the matrix of Table 5.2-2. This table covers each program area (or study), its purpose, number of stations, sampling frequency, reporting interval, sampling definition, calculations made, sample size, spatial and temporal comparisons, number of means compared, hypotheses tested, statistical techniques used, level of significance, and parameters plotted. The hypothesis tested by time series analysis and/or multiple regression and correlation for surface waters is that there is no effect on surface stream quantity and quality and sediment with development. In addition station-to-station comparisons will be made by the same techniques. Specific indicator variables subjected to this analysis are identified in Table 5.2-1.

5.2.2 Springs and Seeps

5.2.2.1 Objectives and Rationale

The flow from natural springs and seeps provides a substantial fraction of volumetric low-level stream flows to Piceance Creek.

TABLE 5.2-1

USGS GAUGING STATION ANALYTICAL PROGRAM

A. Data to be Collected Monthly at Major Stations (007, 022, 058, 061) and Quarterly at other **Stations

1. Alkalinity
*2. Ammonia
*3. Boron
4. Calcium
*5. Fluoride
6. Iron
7. Magnesium
8. Potassium
9. Silica
10. Sodium
11. Biocarbonate
12. Carbonate
13. Chloride
*14. Total dissolved solids
15. Kjeldahl nitrogen
16. Nitrate & nitrite
*17. Arsenic
18. Manganese
19. Phosphate
*20. Dissolved organic carbon
*21. Suspended organic carbon
22. Sulfate
*23. Sediment
*24. Precipitation
*25. pH
*26. Temperature
*27. Flow

B. Data to be Collected Quarterly at Major Stations and Other **Stations

1. Aluminum
2. Bromine
3. Barium
4. Cadmium
5. Copper
6. Chromium
*7. Oil & Grease
*8. Lead
9. Lithium
*10. Mercury
11. Molybdenum
*12. Selenium
13. Sulfide
14. Zinc
15. Cyanide
16. Strontium
17. Fecal coliform
18. Fecal streptococcus
19. Total coliform
20. COD
21. BOD
*22. Phenols
23. Complete element scan
24. Gross alpha radiation. If greater than 4 pci, then analyze for radium 226 and natural uranium.
25. Gross beta radiation. If greater than 100 pci, then analyze for strontium 90 and cesium 137.

C. Data to be Collected Twice Yearly at Major Stations

*1. MBAS (Methylene Blue Active Substance)
2. Sediment pesticides
3. Organic fractionation into:

a. hydrophobic acids, bases & neutrals
b. hydrophilic acids, bases & neutrals

as low and high flow periods as estimated from Baseline.

D. Data to be Collected Annually (Sta 061, 007, 042) Sediment Characterization

* Indicator Variables
** To be sampled on an opportunistic basis on emphemeral streams

Springs are utilized by wildlife, for domestic water sources, and for irrigation. Man-made impoundments around spring sources provide a habitat for varied forms of aquatic life. Although none of the springs studied are actually on the C-b Tract, all are close enough that they may be affected by any changes in the groundwater system caused by mining activities. Any effects on spring flows or water quality will depend on hydrological relationships which are largely unknown. Beside the obvious effect of mine dewatering in reducing spring flows, changes in water quality may be just as important. As was done during the 2 year baseline period, these springs and seeps will be monitored on a routine basis. Refer to Figure 5.2-2 for locations of all springs and seeps.

5.2.2.2 Methods

Table 5.2-3 contains the schedule in which the springs and seeps around C-b will be monitored for water quality and flows. This schedule will be maintained during the Development Monitoring Phase.

5.2.2.3 Experimental Design and Data Analysis

Under natural conditions the quality of surface water in springs and seeps will change slowly but perceptibly with time as was demonstrated by the baseline data. Rates of change are related to rates of flow, which are determined by hydro-geologic considerations. Some groundwater basins unaffected by man show annual fluctuations in quality produced by seasonal variations in precipitation, aquifer recharge, water table levels, and discharge rates. The influence of man and industrial development is often marked as an increase in the amplitude of annual variation in quality along with a progressive decrease in average quality. To observe this change, if it does occur, the schedule of parameters in Table 5.2-3 will be analyzed during the Development Monitoring Phase.

Time series (Table 5.2-2) and multiple correlations and linear regression between parameters will be used to test the hypotheses: 1) that dewatering will not affect water quality and quantity of springs and seeps and 2) construction has no effect on water quality.

5.2.3 Precipitation

Precipitation and evaporation will be measured as specified in Section 6.3.1.

5.2.4 Snowpack and Melt

Snowpack and melt will be measured as noted in Section 8.7.5 on Microclimatic Studies.

Table 5.2-2

Hydrology Analysis Matrix

NUMBER	STUDY TITLE	PURPOSE	NUMBER OF STATIONS	SAMPLING FREQUENCY	REPORTING INTERVAL	SAMPLE DEFINITIONS	CALCULATIONS
5.2.1	USGS GAUGING STATIONS	To fulfill lease requirements.	Thirteen: 4 major and 9 minor.	MONTHLY	MONTHLY	Measurement of water levels, pH, conductivity, flow rate, turbidity, and other parameters listed in Table 5.2-1.	None.
5.2.2	SPRINGS AND SEEPS	To measure the quality & quantity of water in the Tract C-b area.	Nine Stations: S-1, S-2, S-3, S-4, S-6, S-7, S-8, S-9, S-10.	1. Discharge: Weekly at all Stations. 2. Water Quality: Quarterly	1. Weekly 2. Quarterly	Measurement of parameters listed in Tables 5.2-2 and 5.2-3. Sample collected by manual grab method.	None.
5.2.3	PRECIPITATION - Listed in Section 6.3.1 on Climatological Records.						
5.2.4	SNOWPACK AND MELT - Listed in Section 8.7.5 on MicroClimatic Studies.						
5.2.5	IMPOUNDMENTS	To insure that standards for discharge are met (State NPDES Permit).	Systems Dependent (To Be Determined).	Impoundments sampled on routine basis at different depths. Effluent sampling as follows: 1. 3 samples in a 7-day period, giving a 7-day average. 2. 3 samples in each of 3 separate calendar weeks in a 30-day period, giving a 30-day average.	TBD	Measurement of input and of discharge, and of quality of discharge. Shallow wells also monitored for signs of seepage.	Effluents - arithmetic means for 7-day and 30-day periods. Impoundments - water quality TBD.
5.2.6	SHALE DUMPS	To fulfill lease requirements.	Two stations in Sorghum Gulch - One up gradient (USGS 033) and one down gradient (USGS 036) + one sta. in Cottonwood Gulch (USGS 039).	Monthly during period of flow.	MONTHLY	Same as 5.2.1. Shallow wells also monitored for signs of seepage.	None.
5.3.1	ALLUVIAL AQUIFERS	To measure the effect of development on alluvial aquifers off-Tract.	5 proposed sta: A-2A A-3A, A-5A, A-6A, A-7A, +13 old sta: A-1 thru A-13.	Quality: A-2A thru A-7A quarterly; (proposed). A-1, A-8, A-9, A-10, A-11 A-12. Quarterly: Monthly checks for conductivity, pH, Temp., & Dissolved Oxygen (DO). Levels: Continuous at all stations.	Quality quarterly Levels. monthly	Same as 5.2.1. Sample collected by pumping.	Daily water levels reduced to monthly averages and standard deviations.
5.3.2	UPPER AQUIFER (U_1, UPC_1, UPC_2)	To monitor the effects of C-b development on the groundwater system	17 on-tract sta for water quality & water levels & 0 off-tract sta for water levels as indicated on Table 5.3-4	Quality: Semi-Annual. Levels: Monthly.	Quality: Semi-Annual. Levels: Monthly.	Measurement of water levels and analysis of water quality parameters as listed in Table 5.3-5. Sample collected by pumping.	Means and standard deviations of parameters by year.
5.3.3	LOWER AQUIFER (LPC_3, LPC_4)	Same as above.	14 on-tract sta for water quality & water levels & 13 off-tract sta for water levels as indicated on Table 5.3-6.	Same as above.	Same as above.	Same as above.	Same as above.
5.3.4	MINE ORTFI SUMPS (Upper and Lower Levels) Phase II	To monitor for retort produced water quality to assure isolation from regular mine water and groundwater. To monitor mine water quality if reinjection is used.	Systems dependent (To Be Determined)	TBD	TBD	TBD	TBD

NUMBER	SAMPLE SIZE	COMPARISONS SPATIAL	COMPARISONS TEMPORAL	PARAMETER COMPARED	HYPOTHESES TESTED	STATISTICAL TECHNIQUES USED	TEST LEVEL OF SIGNIFICANCE	GRAPHIC PARAMETERS
5.2.1	Varies according to parameter & time of year.	Station vs Station.	Parameter vs Time by station.	Parameters listed in Table 5.2-1.	H_0: There is no effect on surface stream quantity and quality or on sediment characterization with development.	Single and multi variable time series, regression, and correlation.	± 20% of max or min or professional judgement.	Hydrographs of flow (cfs) vs time - Quality Parameters vs time.
5.2.2	One sample per station.	Station vs Station.	Parameter vs time by station.	Parameters listed in Tables 5.2-2 & 5.2-3.	H_0: Dewatering will not affect the springs and seeps on Tract (in quality or quantity). H_0: Construction has no effect on water quality (baseline vs D).	Same as above.	Same as above.	Same as above.
5.2.3	Precipitation - Listed in Section 6.3.1 on Climatological Records.							
5.2.4	Snowpack and Melt - Listed in Section 8.7.5 on MicroClimatic Studies.							
5.2.5	Seven one-liter bottles per sample (effluents).	Parameters vs Limitations as follows TSS - 30-45mg/l; O & G - 10mg/l; F - daily 3mg/l; 30 days 2mg/l; B - daily .75mg/l; 30 days .75mg/l, pH - 6-9, TDS - daily 1500mg/l; 30 days 1000mg/l.	None.	Parameters listed in the spatial comparisons.	None.	None.	NA	Parameter vs time.
5.2.6	Varies according to parameter & time of year.	None.	Parameter vs Time by station.	Same as 5.2.1.	H_0: No effect on surface stream quality or quantity with development.	Correlation with revegetation and other biological parameters. Single & multi variable time series.	± 20% of max or min or professional judgement.	Quality and Quantity vs time by station.
5.3.1	Seven one-liter bottles per sample, 1 sample per station.	Station vs Station.	Parameters and levels by station over time.	Same as 5.2.1	H_0: Dewatering of Tract C-b will not affect alluvial aquifers in the Tract area. H_0: No effect on alluvial aquifers from surface development.	Correlation of dewatering with level measurements; time series analysis.	Same as above.	Quality parameters and levels vs time.
5.3.2	Same as above	Station vs Station.	Quality and levels by station vs time	Parameters listed in Table 5.3-5.	H_0: No effect on surface water quality with dewatering, treating, or discharging, or by reinjection.	Same as above.	Same as above.	Quality and quantity vs. time by station.
5.3.3	Same as above.	Station vs Station.	Same as above.	Same as above.	H_0: Same as above.	Same as above.	Same as above.	Same as above
5.3.4	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

ABBREVIATIONS

B Boron
CFS Cubic feet per second
D: Development
F Fluorine
LPC: Lower Parachute Creek
MG/L: Milligrams per liter
NPDES: National Pollutant Discharge Elimination System
O & G: Oil and Gas
TBD: To be determined
TDS: Total dissolved solids
TSS: Total suspended solids
U: Uinta aquifer
UPC: Upper Parachute Creek
USGS: United States Geological Survey

SPRINGS AND SEEPS AROUND
Cb TRACT
Figure 5.2-2

TABLE 5.2-3

SPRINGS AND SEEPS

MONITORING SCHEDULE

(See Figure 5.2-2 for Station Locations)

WEEKLY

Discharge of the following springs and seeps will be measured on a weekly basis:
S-1, S-2, S-3, S-4, S-6, S-7, S-8, S-9, S-10

MONTHLY

Each month the springs and seeps will be checked for pH*, conductivity*, DO*, and temperature*. If the values are more than 20% below minimum baseline values or more than 20% above maximum baseline values, additional water quality samples will be obtained.

QUARTERLY

All springs and seeps will be sampled quarterly and analyzed for the following parameters:

Ag	Mo	Ca	*TDS
*As	Cl	Mg	SO_4
Ba	Li	*Fluoride	CO_3
Cd	Al	*B	HCO_3
Cr	Sr	Ni	NO_3
Cu	Se	Oil & Grease	Alkalinity
Fe	Zn	Temperature	Hardness
Hg	*pH	Kjeldahl-N	*Phenols
Mn	Na	COD	*Ammonia
Pb	K	BOD	

SEMI-ANNUALLY

Bacteriology - Fecal, Total Bact.
Radiology
DOC Fractionation, 2 springs to be Selected in Coordination with AOSO

ANNUALLY

Bromine
All analyses except BACT., Radiology, and DOC will be performed at Occidental's Grand Junction Lab.

*Indicator Variables

5.2.5 Impoundments

According to present development plans for C-b, one or more retention dams will be located on the Tract. Solar evaporation ponds will also be constructed on Tract. The USGS gauging stations will monitor for any accidental discharges from the evaporation ponds. Dams will be constructed to hold mine-treated water.

Impoundments will be sampled on a routine basis at different depths. A detailed monitoring schedule will be forwarded to the AOSO for their approval as soon as the exact number and location of impoundments are determined. All periodic discharges (if any) from any dam to Piceance Creek will also be monitored for the parameters indicated on Table 5.2-1 to make certain all these discharges meet Federal and State regulations. Options of sprinkling and reinjection are also being considered if needed when dewatering begins (also subject to AOSO approval). These systems will be monitored on a continuous basis to make certain all Federal and State regulations are met.

Soil moisture profiles will be determined to depths of at least 20 feet at stations to be determined downstream of impoundments and water application sites.

Water quality parameters as plotted functions of time for impoundment variables will provide visual analyses of departures from expected levels. Soil moisture profiles will also be plotted.

5.2.6 Dumps - (Shale Piles)

Raw mine rock will be stored in Cottonwood and Sorghum Gulches. These dumps will be monitored for any water seepage by the USGS Gauging Stations (036 and 039) at the mouths of Cottonwood and Sorghum Gulch and upgradient of Sorghum Gulch by Sta. (033). These stations will be continuously monitored for water quantity and quality. In addition shallow wells in the same vicinity will also assist in monitoring for seepage-related indicators.

Correlations with vegetation and other biological parameters will be evaluated by time series and multiple correlation techniques. Shallow wells will be correlated for potential seepage.

5.3 Sub-Surface Water

Degradation of the groundwater system in the shallow alluvial aquifers would eventually affect surface waters. However, in order to detect any changes in the shortest possible time, a series of alluvial monitoring wells near potential sources are utilized. If surface water degradation is detected, the inspection of groundwater records may be valuable in pinpointing the source.

Because of the longer time scale involved in groundwater movements (weeks or months may be required to move relatively short distances), the location of monitoring sites is much more critical than for surface water in order to detect pollution before a significant buildup occurs in the system. Site selection must be based on a general knowledge of the area hydrology as well as on an analysis of the possible pollution sources. To provide general area coverage, the present network of alluvial wells will be maintained. Local conditions not withstanding, the general hydraulic gradient slopes northward. All monitoring wells will therefore be placed northward of possible pollution sources. Where the slope deviates from the general trend, the monitoring wells will be placed so as to reflect any changes in the local drainage basin. As a general guideline, it is expected that one shallow monitoring well will be placed within 100 ft. down-gradient of each potential reinjection well. Monitoring wells will also be placed a short distance downstream from each reservoir and growing raw shale piles. These locations are near the center of the groundwater drainage pattern and are no further downstream than the intersection with the next larger tributary branch. For the wide sources, more than one well is planned. Well numbers and construction will be such as to allow sampling from different depths within the saturated interval. Coordination with the AOSO is required.

5.3.1 Alluvial Aquifers

5.3.1.1 Objectives and Rationale

Alluvial wells were drilled in all gulches at C-b and in the major drainages of Piceance Creek, Willow Creek, and Stewart Gulch. These wells were sampled over the 2-year baseline period and will be used for monitoring during development of C-b. They will be used in conjunction with additional wells as needed, to detect any seepage from the main dumps in Cottonwood and Sorghum Gulches, leakage from any proposed water storage dams, any accidental spills from everyday plant operations, and runoff from construction activities. In addition to these wells, 5 more shallow alluvial wells are proposed to monitor the upper part of the saturated zone to detect any near-surface pollutants. These will be designated A-2A, A-3A, A-5A, A-6A, and A-7A. See Figure 5.3-1 for locations.

5.3.1.2 Methods

The schedule in Table 5.3-1 will be used for water quality and water level measurement through development of C-b for all alluvial wells.

5.3.1.3 Experimental Design and Data Analysis

Under natural conditions the quality of alluvial water will change slowly with time. The desirable frequency for monitoring

Alluvial Aquifer Monitoring Network With Propsed New Alluvial Wells;
A-2A, A-3A, A-5A, A-6A, A-7A

Figure 5.3-1

TABLE 5.3-1

WATER QUALITY MEASUREMENTS IN ALLUVIAL WELLS

(Station locations given in Figure 5.3-1)

Monthly

Field Measurements: pH,* Conductivity,* Temperature,* DO, Water level* measurement to define reliability of Steven's Recorder.

Quarterly

Field Measurements and Water Quality Samples

Ag	Mn	Zn	*Oil and Grease
*As	Pb	Na	Kjeldahl N
Ba	Mo	K	COD
Cd	Cl	Ca	Phenols
Cr	Li	Mg	*TDS
Cu	Al	*Fluoride	SO_4
Fe	Sr	*B	CO_3
Hg	Se	Ni	HCO_3
Alkalinity	Hardness	Ammonia	No

Semi-Annually

Additional Parameters for Analysis

*Bacteriology: Fecal and Total Coliform
Radiology
DOC (Fractionation)
BOD

Annaully

Bromine
MBAS
Stations A-2, A-3, A-5, A-6 and A-7 will be monitored at a reduced frequency after the proposed alluvial wells, A-2A, A-3A, A-5A, A-6A, and A-7A are completed. All analyses except Bacteriology, Radiology, DOC, BOD, and MBAS will be performed at Occidental's Grand Junction lab.

* Indicator Variable

water quality depends upon its sensitivity to natural and man-made influences and upon the pace of industrial development. Where effluents are being discharged directly and are subject to rapid changes in composition, sampling will be consistent with regulations. To characterize changes in near-surface aquifers, a monthly or quarterly frequency is adequate. Parameters analyzed are indicated on Table 5.3-1. Effects of shale mining and dewatering will be evaluated through time-series and correlation analyses of the water quality and quantity parameters as indicated on Table 5.?-2.

5.3.2 Upper Aquifer (UPC_1, UPC_2)

See Figure 5.1-1

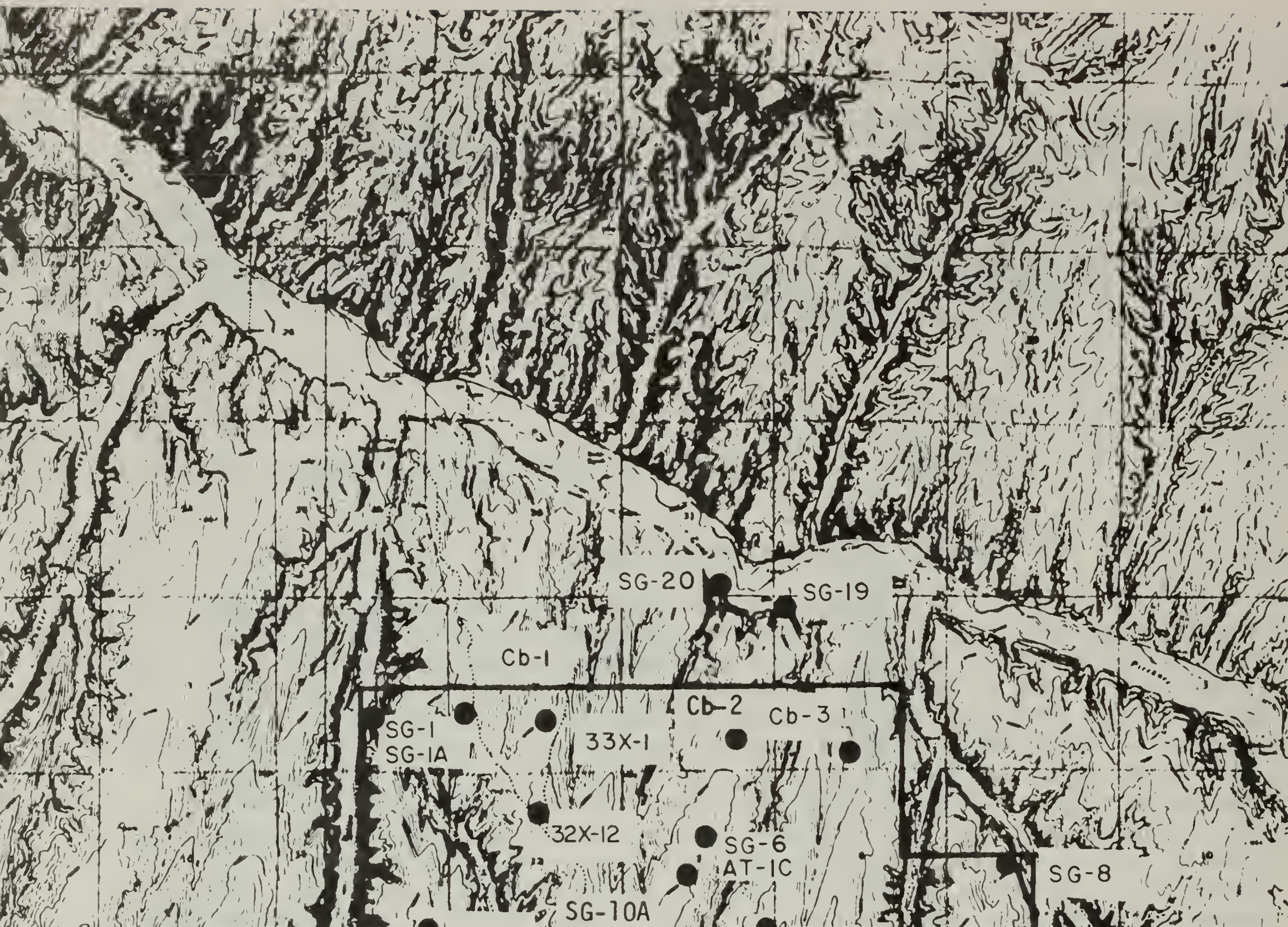
5.3.2.1 Objectives and Rationale

Analysis of the hydrologic testing which has been completed on C-b Tract to date indicates that the simplified concept of an "upper aquifer" is in reality a more complex system comprised of highly stratified layers of different permeability. With the present mine design, water of the UPC_2 zone will be commingled with the waters of the LPC_3 zone. During the first phase of shaft sinking very little, if any, stress will be put on the upper aquifer. During the next phase of ancillary development, the major stress will be applied on this aquifer by lateral drifting and subsequent dewatering. As this phase of development progresses, the upper aquifer will be monitored with present drill holes on and off Tract. Additional completion of existing holes and perhaps additional holes, will be made to isolate the upper portion of the UPC_1 zone, which is highly productive and permeable only in the northwest part of the C-b Tract, from the UPC_2 aquifer subunit. Any effect of mine dewatering on the UPC_1 zone will be monitored. However, it is predicted, with the present scheme for dewatering, effects above the 4 Senators Zone will be minimal. It is believed the 4 Senators Zone acts as an aquitard or possibly an aquiclude prohibiting vertical movement of water within the "Upper Aquifer." Hence surface effects of dewatering would be minimized. Refer to Figure 5.3-2 for locations of the deep hole monitoring network maintained by the C-b operation. Figure 5.3-3 shows the locations of additional monitoring wells which are not affiliated with C-b Tract. Water level data from these wells will be obtained to better gauge the effects of mine dewatering.

5.3.2.2 Methods

The upper aquifer environmental monitoring program is designed to monitor the following major bedrock aquifer units as defined previously in Section 5.1.

The monitoring program uses the present wells on and off Tract. In general, modifications will be made in the shallow tubing strings so that the sections above and below the 4 Senators Zone can be monitored separately.



DEEP WELL MONITORING NETWORK
Cb TRACT
Figure 5.3-2

ADDITIONAL OFF-TRACT WELLS TO BE MONITORED (BOXED IN ON FIGURE)

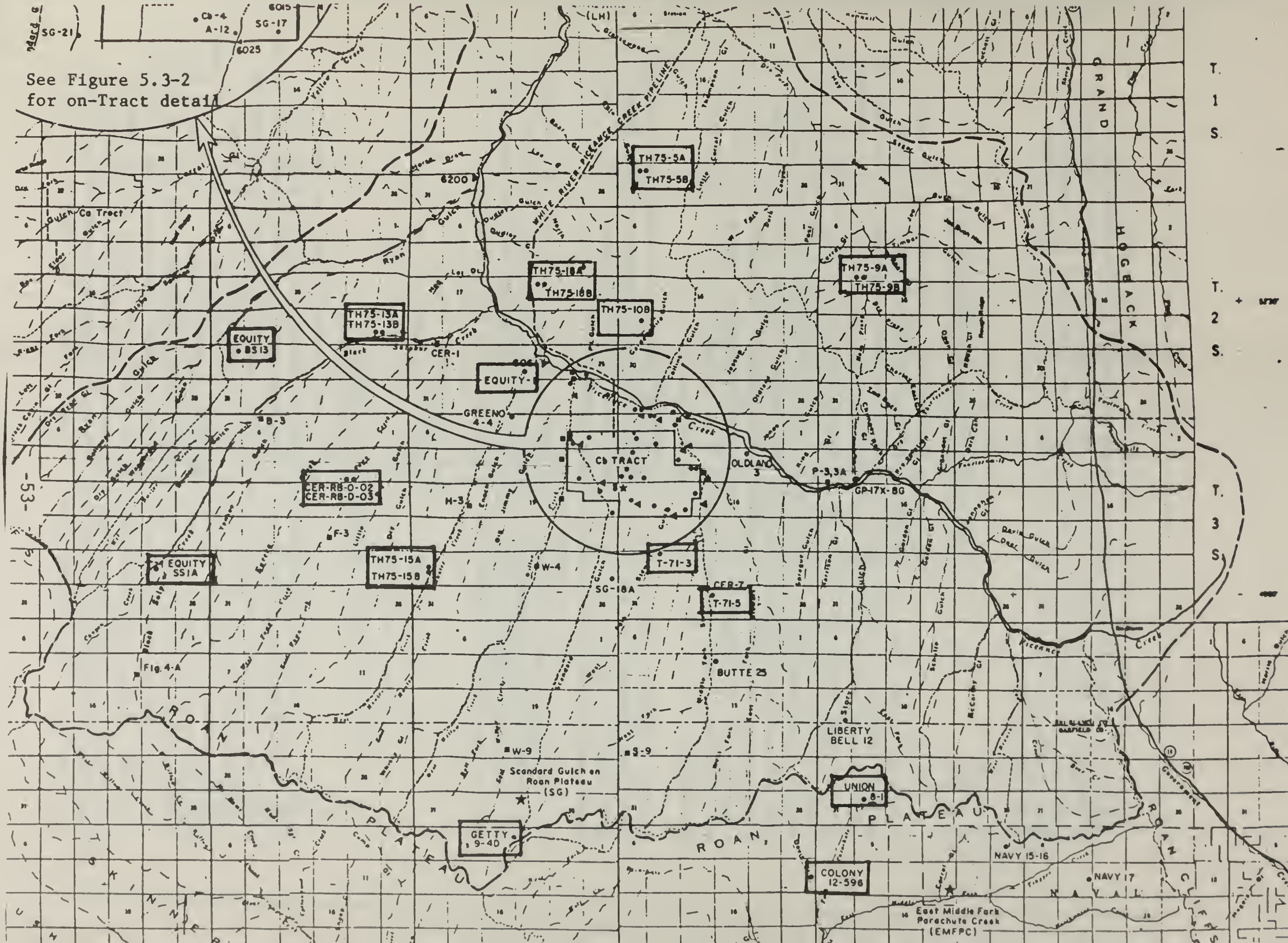


Figure 5.3-4 shows the present completion of deep wells on Tract. Figure 5.3-5 contains the planned recompletions of existing deep wells to correspond to the stratified aquifer configuration and present dewatering plans. Table 5.3-2 is the intended procedure to be used to complete each hole on and off Tract and the units that particular hole would monitor after recompletion.

5.3.2.3 Experimental Design and Data Analysis

The monitoring program is designed to monitor according to the baseline schedule used from 1974-1977 until the upper aquifer holes are recompleted. Table 5.3-3 shows the old monitoring network before recompletions (for the Upper Aquifer) and the new monitoring network after recompletions are made (now designated at levels UPC_1 and UPC_2). Also shown are non C-b wells off-tract which monitor the Upper Aquifer and will provide additional water level data. "Close in" refers to wells located near the ancillary development area and "Remote" refers to holes located further away from the early stages of development. Scheduling for recompletions, to the extent known, appears on Table 5.3-2. Note that C-b-1 is not included in this diagram because it is scheduled to be "plugged and abandoned."

All water quality sampling will be on a semi-annual basis with sampling done in May and November of each year. Water level measurements will be taken each month for all holes. Table 5.3-4 is a list of the water quality parameters which will be analyzed for each sampling period.

The hypothesis tested (Table 5.2-2) is that there is no effect on surface-water quality with dewatering, treating, discharging, or by injection. Correlation of dewatering with water level measurements will be made as will time series analysis, water quality graphics, and trend analysis.

5.3.3 Lower Aquifer (LPC_3, LPC_4)

5.3.3.1 Objectives and Rationale

As noticed in the previous section of the upper aquifer, the lower aquifer is also a complex system of highly stratified units of different permeability. During the ancillary development stage when the major stress is applied to the aquifers and with subsequent dewatering, existing deep holes on and off Tract will be monitored for quality and quantity effects produced by the withdrawal of mine water. Figure 5.1-1 shows the lower aquifer subdivided into the LPC_3 and LPC_4 zones. A portion of the LPC_3 subdivision of the aquifer system below the Mahogany Zone will be subjected to dewatering. Present mining plans do not call for operations below the R-5 zone and thus incursions into the LPC_4 will not be made during mining activities. To monitor the effect of dewatering a portion of the LPC_3 interval, the recompletions of wells given in Table 5.3-2 and Figure 5.3-5 are necessary. The Mahogany Zone is judged to be an impermeable barrier so

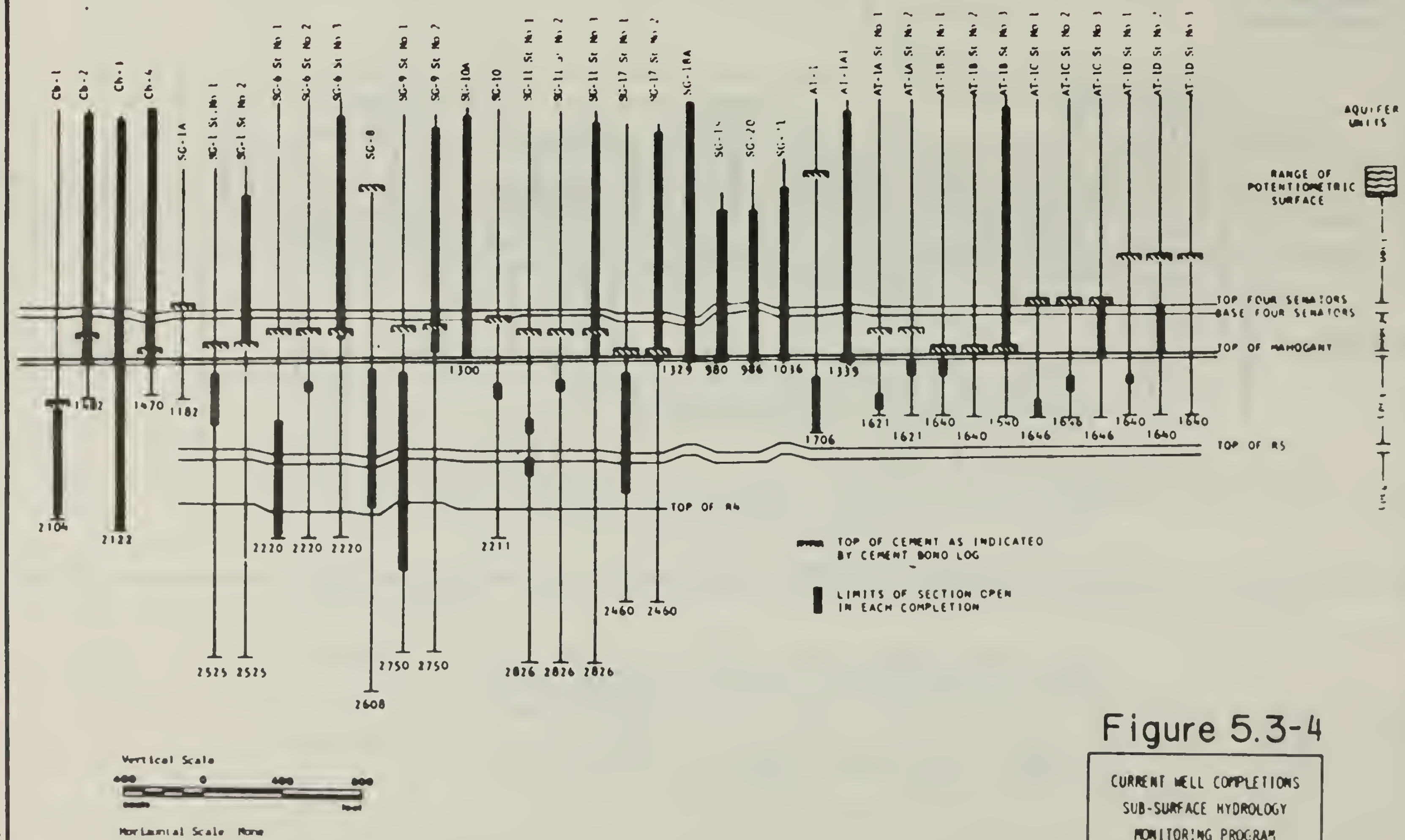


Figure 5.3-4

CURRENT WELL COMPLETIONS
SUB-SURFACE HYDROLOGY
MONITORING PROGRAM
TRACT C-B

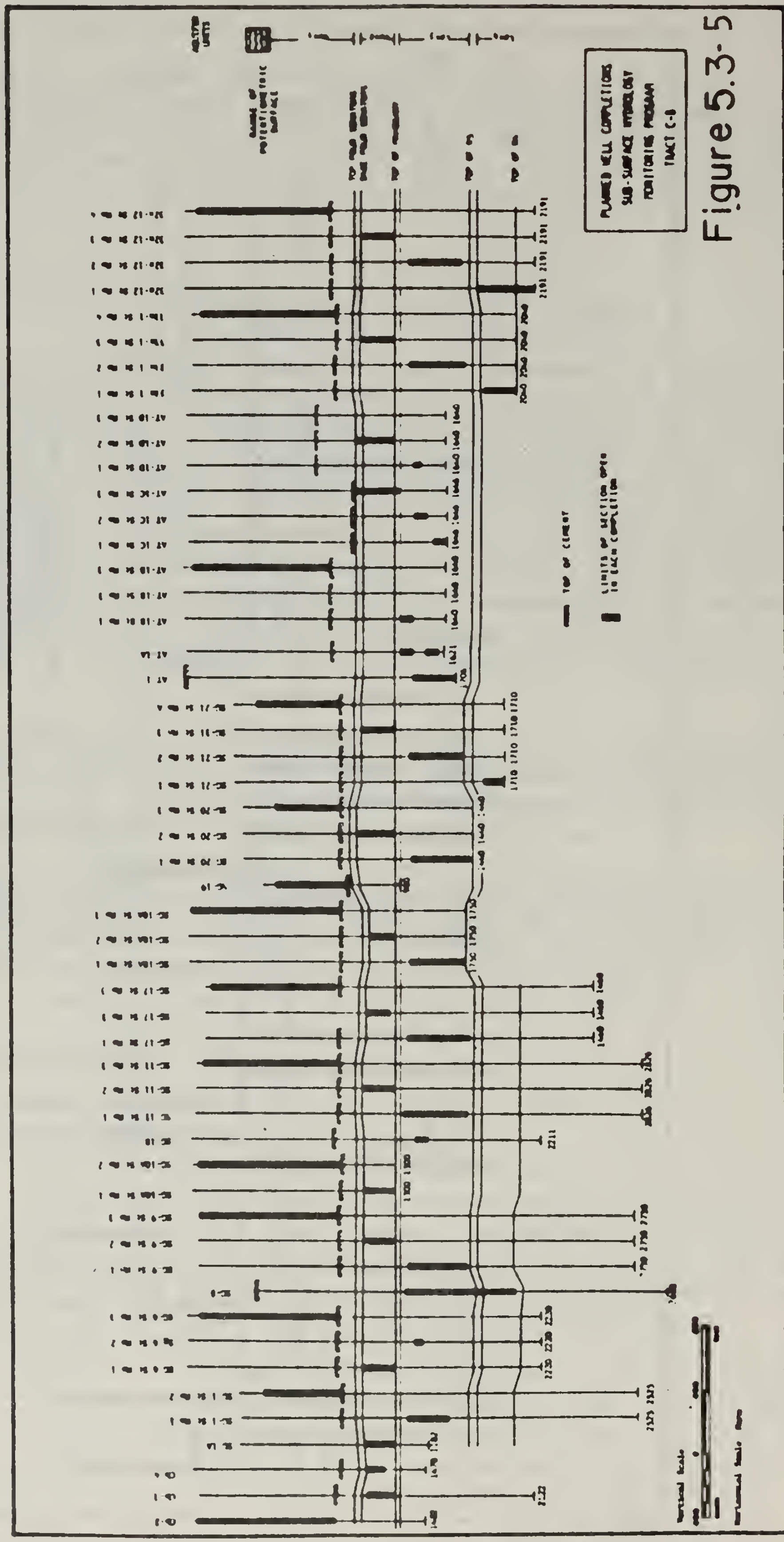

PLANNED WELL COMPLETIONS
SUB-SURFACE HYDROLOGY
MONITORING PROGRAM
TRACT C-B
TOP OF CEMENT
LIMITS OF SECTION OPEN IN EACH COMPLETION

Figure 5.3-5

TABLE 5.3-2

MODIFICATION FOR EXISTING TRACT C-b MONITORING WELLS
FOR MONITORING OF DEWATERING AND REINJECTION

WELL NAME	DESCRIPTION OF WORK REQUIRED	FINAL STATUS
Cb-1	Set 2 bridge plugs at 1775'. Set 1 bridge plug at 1530'. Cut 2-3/8" tubing at 1480'. Spot cement plug 1480' - 980' (approx. 100 ft^3). Spot 10' cement plug at surface.	Plugged and abandoned.
Cb-2	Cut tubing at 1140' and pull. Spot cement plug 1140' - 900' (approx. 35 ft^3). Tag cement and dress off to PBTD of 900'. Run tubing in open ended to 850'.	Upc_1
Cb-3	Pull tubing. Sand well back to 1850'. Spot cement plug 1850' - 1700' (approx. 25 ft^3). Tag plug. Sand well back to 1400'. Spot cement plug 1400' - 1250' (approx. 25 ft^3). Tag plug. Run 4" flush joint casing and cement at 1250' raising cement to 875'. Perforate with 1 shot/ft 1250' - 1080'.	Upc_2
Cb-4	Set 2 bridge plugs at 1290'. Cut 2-3/8" tubing at 1225' and pull same. Run 4" flush joint casing and cement at 1225' raising cement to 950'. Perforate with 1 shot/ft from 1215' - 1100'.	Upc_2
SG-1	Cut string No. 2 at 890'. Raise cement plug 890' - 650' (approx. 50 ft^3). Run string No. 2 open ended to 600'.	St No. 1 Lpc_3 St No. 2 Upc_1
SG-1a	Run CBL. If cement top above 700' perforate 2-3/8" 780' to 980' with 1 shot/ft.	Upc_2
SG-6	String No. 3: Cut tubing at 1150'. Raise cement plug 1150' - 950' (approx. 75 ft^3). Run string No. 3 open ended to 900'. String No. 1: Set 3 bridge plugs at 1600', 1810', 1840'. Perforate with 1 shot/ft from 1310' - 1110'.	St No. 1 Upc_2 St No. 2 Lpc_3 St No. 3 Upc_1

WELL NAME	DESCRIPTION OF WORK REQUIRED	FINAL STATUS
SG-19	Plug well back by bradenhead squeezing down 4" with 200 ft^3 of cement followed by a wiper plug. Displace plug to 750' using hesitation squeeze technique. Run CBL. If the cement is above 650' perforate above the cement with 10 holes. If cement is below 650' resqueeze to effect separation of Upc_1 and Upc_2, then perforate above 650' with 10 holes.	Upc_1
SG-20	Pull 4" casing. Deepen well to 1440' (top of R5). Run string No. 1 (2-3/8" tubing) to 1440 and cement string in raising the top to 950' (approx. 100 ft^3). Run CBL. Run string No. 2 (2-3/8" tubing) to the top of cement (approx. 950') and cement string in raising the top of cement to 600' (approx. 75 ft^3). Run string No. 3 (1-1/2" tubing) open ended to 550'. Perforate string No. 1 with 1 shot/ft from 1420' to 1050'. Perforate string No. 2 with 1 shot/ft from 940' to 740'.	St No. 1 Lpc_3 St No. 2 Upc_2 St No. 3 Upc_1
SG-21	Pull 4" casing. Deepen well to 1710' (into L5). Run string No. 1 (2-3/8" tubing) to 1710' and cement string in raising the top to 1475' (approx. 60 ft^3). Run CBL. Run string No. 2 (2-3/8" tubing) to the top of cement (approx. 1475') and cement string in raising the top of cement to 1010' (approx. 100 ft^3). Run CBL. Run string No. 3 (2-3/8" tubing) to the top of cement (approx. 1010') and cement string in raising the top of cement to 650' (approx. 130 ft^3). Run string No. 4 (2-3/8" tubing) open ended to 550'. Perforate string No. 1 with 1 shot/ft from 1700' - 1565'. Perforate string No. 2 with 1 shot/ft from 1450' to 1110'. Perforate string No. 3 with 1 shot/ft from 1000' to 820'.	St No. 1 Lpc_4 St No. 2 Lpc_3 St No. 3 Upc_2 St No. 4 Upc_1
AT-1A1 & AT-1C	Pull 4" casing. Spot cement plug 1100' to 900' (approx. 60 ft^3). Cap well.	Plugged
AT-1A	Pull 2" tubing. Run retrievable bridge plug set at 1300' and cap with sand. Perforate 4" with 2 holes at 1170' and break circulation. Recement 4" through perfs raising cement top to 900'. Clean out cement and pressure test casing to 500 psi. Pull bridge plug.	Lpc_3

WELL NAME	DESCRIPTION OF WORK REQUIRED	FINAL STATUS
SG-9	Run a third string of 2-3/8" tubing to 1070' and raise cement plug 1070' - 900' (approx. 60 ft^3). Run string No. 3 open ended to 850'. Clean out string No. 2 to 1260'. Run CBL. Perforate string No. 2 with 1 shot/ft from 1250' to 1060'. Set 3 bridge plugs at 1710'.	St No. 1 Lpc_3 St No. 2 Upc_1
SG-10	Pull 2-3/8" tubing. Set a retrievable bridge plug at 1350' and cap with sand. Perforate 4" casing with 2 holes at 1080'. Break circulation and recement 4" raising cement to 900' (approx. 50 ft^3). Clean out 4" and pressure test to 500 psi. Pull BP and swab test perfs.	Lpc_3
SG-10a	Pull 4" casing. Ream hole out to 6-1/4" to 950'. Run string No. 1, 2-3/8" tubing to 1300' and cement raising the cement to 950' (approx. 75 ft^3). Run CBL to verify cement top. Run string No. 2, 2-3/8" tubing, to 900' open ended. Perforate string No. 1 1290' - 1110' with 1 shot/ft.	St No. 1 Upc_2 St No. 2 Upc_1
SG-11 (beneath disposal pile)	Cut string No. 3 at 1115' and pull. Raise cement plug 1115' to 900' (approx. 90 ft^3). Run string No. 3 open ended to 850'. Set bridge plug in string No. 1 at 1775'. Perforate string No. 1 with 1 shot/ft from 1730' to 1325'. Set bridge plug in string No. 2 at 1370'. Perforate string No. 2 with 1 shot/ft from 1270' to 1075'.	St No. 1 Lpc_3 St No. 2 Upc_2 St No. 3 Upc_1
SG-17	Cut string No. 2 at 1180' and pull. Run 2-3/8" tubing (string No. 2) to 1180' and cement string in raising the top to 850' (approx. 90 ft^3). Run CBL. Run string No. 3, 1-1/2" tubing to 800' open ended. Perforate string No. 2 with 1 shot/ft from 1170' to 1030'. Set 3 bridge plugs in string No. 1 at 1690', 1715' and 1740'.	St No. 1 Lpc_3 St No. 2 Upc_2 St No. 3 Upc_1
SG-18a	Pull 4" casing. Deepen well to 1750' (top of R5). Run string No. 1 (2-3/8" tubing) to 1750' and cement string in raising the top to 1300' (approx. 125 ft^3). Run CBL. Run string No. 2 (2-3/8" tubing) to the top of cement (approx. 1300') and cement string in open ended to 900'. Perforate string No. 1 with 1 shot/ft from 1750' to 1400'. Perforate string No. 2 with 1 shot/ft from 1290' to 1135'.	St No. 1 Lpc_3 St No. 2 Upc_2 St No. 3 Upc_1

WELL NAME	DESCRIPTION OF WORK REQUIRED	FINAL STATUS
AT-1B	Pull string No. 3. Spot cement from 1200' to 900'. Run string No. 3 in open ended to 850'.	St No. 1 Lpc_3 St No. 3 Upc_1

TABLE 5.3-3

UPPER AQUIFER MONITORING NETWORK

(BEFORE RECOMPLETIONS)

UPPER AQUIFER

Cb-2	SG-10A
Cb-4	SG-11 #3
AT-1C #3	SG-17 #2
SG-1 #2	SG-18A
SG-6 #3	SG-19
SG-8 #2	SG-20
SG-9 #2	SG-21

AFTER RECOMPLETIONS — UPC_1, UPC_2

CLOSE IN ANCILLARY DEVELOPMENT	REMOTE DURING ANCILLARY DEVELOPMENT
Cb-2 (UPC_1)	Cb-2 (UPC_2)
SG-1 #2 (UPC_1)	Cb-4 (UPC_2)
SG-1A (UPC_2)	SG-9 #2 (UPC_2)
SG-6 #3 (UPC_1), #1 (UPC_2)	SG-11 #2 (UPC_2), #3 (UPC_1)
SG-10A#1 (UPC_2), #2 (UPC_1)	SG-17 #2 (UPC_2), #3 (UPC_1)
SG-20 #2 (UPC_2), #3 (UPC_1)	SG-18A#2 (UPC_2), #3 (UPC_1)
AT-1B #3 (UPC_1)	SG-19 (UPC_1)
	SG-21 #3 (UPC_2), #4 (UPC_1)

ADDITIONAL UPPER AQUIFER MONITORING WELLS

WELL DESIGNATION	OWNER OF WELL
TH 75 - 5A	Federal Government
TH 75 -13A	Federal Government
TH 75 -18A	Federal Government
TH 75 - 9A	Federal Government
CER RB - D - 02	Federal Government
TH 75 -15A	Federal Government
Union 8 - 1	Union Oil Company
Colony 12 - 596	Atlantic Richfield

TABLE 5.3-4

WATER QUALITY PARAMETERS SAMPLED IN THE UPPER AND LOWER AQUIFERS

Monthly

* Water level

Semi-Annually

Field measurements: *ph, *temperature, dissolved oxygen, conductivity

Ag	Pb	K	NO_3
*As	Mo	Ca	HCO_3
Ba	Cl	Mg	CO_3
Co	Li	*Fluoride	SO_4
Cr	Al	*B	*TDS
Cu	Sr	Ni	Kjeldahl N
Fe	Se	*BOC	*Oil and Grease
Hg	Zn	Phenols	
Mn	Na	Ammonia	
BOD	COD	Hardness	
*Radiology	Br	Alkalinity	

Annually

**PNA (Selected hole or holes and species analyzed will be determined at a later date.)

* Indicator Variables
** To be run by an independent laboratory

that potential subsequent dewatering in the LPC_3 and LPC_4 zones will have minimal effects on the upper zones over the short term.

5.3.3.2 Methods

Figure 5.3-2 shows the location of the deep-hole monitoring network which will be used for monitoring the effects on the groundwaters during development of C-b. As in the case of the "upper aquifer," the deep tubing strings will also be recompleted to correspond to the multiaquifer concept. The wells as presently completed observe the entire "lower aquifer" from the Mahogany Zone to terminal depth of all holes. With the planned completions these separate units will be isolated and monitored separately.

5.3.3.3 Experimental Design and Data Analysis

The baseline holes ("before recompletion") will be monitored until the planned recompletions are finished. Then the well locations will be modified according to Table 5.3-5; designated "after recompletions." Water levels associated with the lower aquifer will also be noted in wells in the vicinity of the Tract shown in Table 5.3-5.

Time series and correlations among the relevant water quality parameters will be used to assess the impact of mine water and retort operations for water quality and quantity.

All water quality sampling will be according to the same schedule as the upper aquifer holes with sampling done on a semi-annual basis. Water levels will be measured monthly. Table 5.3-4 lists the water quality parameters to be analyzed at each sampling period. Hypotheses to be tested are identical to those for the upper aquifer.

5.3.4 Mine Drift Sumps (All Levels)

Under the present mining scheme, sumps in the upper "Air Level" and lower "Production Level" will be the main points of water collection during the ancillary development stage. At the present time, the exact technique of water handling has not been decided. Under consideration for dewatering are treatment of mine inflow water and discharge, reinjection of mine inflow water, consumptive use (depending on amount of water encountered), irrigation, sprinkling, or a combination of any of the above. Depending on the method chosen, a quality control design will be chosen to meet all Federal and State water quality regulations and AOSO requirements for discharges for the protection of the groundwater system.

5.3.5 Retort-Produced Water: Retorting Phase

During the retorting phase of Ancillary Development and Commercial Mine Operation, the need is apparent for a detailed sampling

TABLE 5.3-5

LOWER AQUIFER MONITORING NETWORK

(BEFORE RECOMPLETIONS)

LOWER AQUIFER

Cb-1	SG-9 #1
AT-1C #1	SG-10
AT-1C #2	SG-10R
SG-1 #1	SG-11 #1R
SG-6 #1	SG-11 #2
SG-6 #2	SG-17 #1R
SG-8R	

(AFTER RECOMPLETIONS)

LPC_3, LPC_4

CLOSE IN - ANCILLARY DEVELOPMENT	REMOTE - ANCILLARY DEVELOPMENT
SG-1 #1 (LPC_3)	SG-9 #1 (LPC_3)
SG-6 #2 (LPC_3)	SG-11 #1 (LPC_3)
SG-10 (LPC_3)	SG-17 #1 (LPC_3)
SG-20 #1 (LPC_3)	SG-18A #1 (LPC_3)
AT-1A (LPC_3)	SG-21 #1 (LPC_4), #2 (LPC_3)
AT-1B #1 (LPC_3)	SG-8

ADDITIONAL LOWER AQUIFER MONITORING WELLS (Figure 5.3-2a)

Well Designation	Owner of Well
TH 75 - 5B	Federal Government
TH 75 -13B	Federal Government
Equity 1	Equity Oil Company
TH 75 -18B	Federal Government
TH 75 -10B	Federal Government
TH 75 - 9B	Federal Government
Equity Sulfur 1A	Equity Oil Company
CER RB - D - 03	Federal Government
TH 75 -15B	Federal Government
T - 71 - 3	TOSCO
T - 71 - 5	TOSCO
Getty 9 - 4D	Getty Oil Company
Equity BS - 13	Equity Oil Company

program on the deposition of "retortproduced water." Detailed quality control will be maintained on the water produced during retorting both before treatment and after treatment and it will be isolated from other waters. This water will either be used consumptively during operations or will be disposed of in a manner that is environmentally acceptable. Further detail will be provided in annual reports as engineering details are developed.

5.4 Development - Related Monitoring

A hydrological monitoring program should contain provisions for periodic review and modifications as justified by changing conditions or by additional interpretation of the record. Monitoring of retort waters falls in this category, for example. A convenient format for this review is provided by the required annual report. Types of changes which might be suggested are, for example, more frequent analyses for specific constituents related to development activities, less frequent analyses of constituents found to be stable with time, or additional shallow monitoring wells if significant changes in water quality are observed in the alluvial aquifer. The monitoring network devised for this plan is comprehensive and versatile enough to detect any significant water quality effects. If such changes occur, however, it may be desirable to increase the monitoring coverage in the region of change. This may be desirable in order to more precisely quantify the effects, or to map the source, or to reduce the lag time when studying the effectiveness of corrective actions.

While it is not expected that Development Monitoring results will be appreciably different from those obtained during Baseline, there is a chance that additional data may change the picture somewhat. For example, additional water level data and a refinement of the analysis could either confirm or disprove the hypothesis of a hydraulic connection between the springs and deep aquifers. The emphasis on monitoring of the different geologic units above the mine zone might be shifted accordingly.

Development of ecological interrelationships might also suggest changes in the hydrological monitoring program. This continuing effort may suggest that certain water quality parameters are of more critical importance than presently perceived. Additional coverage in some area, or different analytical techniques might be required.

5.5 Systems Dependent Monitoring

During the two-year baseline period, large volumes of data were obtained and interpreted. These two-years of baseline data provide an indication of baseline hydrological conditions existing prior to development of C-b. Normal water quality conditions, monthly or yearly water level fluctuations, and yearly stream flow fluctuations have been recorded. With these data, the next phase of monitoring should be able to differentiate between baseline conditions and give early signs of perturbations caused by major development of the Tract. If some changes occur, early warning will allow for corrective steps to be taken at the earliest possible time, thus increasing the chances

for the least possible disturbances to wildlife and humans. Appropriate systems dependent monitoring programs can be initiated, as required.

5.6 Quality Assurance

A quality assurance program for C-b hydrological monitoring is a necessity in order to obtain the highest quality data. The following steps will be taken to assure that this is accomplished.

5.6.1 Water Quality Monitoring

For water quality monitoring, a standard operating procedure is to be documented and adhered to so that data gathered are consistent with respect to instrumentation, well location and with time. Spot checks by an independent (staff) observer will be made to verify that the prescribed procedure is being followed. This procedure will be laid out in detail as to specific operations and the time for each.

The following is the detailed procedure for sample collection.

Preparation of 1 liter glass bottles for sample collection

Bottle #1	Untreated Filtered through 0.45 Micron Filter (Refrig.)			
(Grand Jct.)	Boron	Lithium	Solids--Dissolved	
	Chloride	Nitrate	Sulfate	
	Fluoride	Potassium		
	Hardness	Sodium		
Bottle #2	Filtered and Aciditied (5 ml. HNO_3)			
(Grand Jct.)	Aluminum	Chromium	Manganese	Zinc
	Arsenic	Copper	Molybdenum	
	Barium	Iron	Nickel	
	Cadmium	Lead	Silver	
	Calcium	Magnesium	Strontium	
Bottle #3	Unfiltered and Untreated (Refrig.)			
(Grand Jct.)	Alkalinity (Carbonate & Bicarbonate)			
	BOD			
	Bromide			
Bottle #4	2 ml. H_2SO_4			
(Grand Jct.)	Oil and Grease	COD	Ammonia	
Bottle #5	1 gm. $CuSO_4$ + 5 ml. H_3PO_4			
(Grand Jct.)	Phenol			
Bottle #6	40 mg. HgC12/L			
(Outside Lab)	Kjeldahl Nitrogen			

Bottle #7 (Outside Lab)	<u>Unfiltered, Untreated, Well Mixed</u>	
	Bacteriology	TOC
	POM	S_2O_3
	DOC	

Bottle #8 (Outside Lab)	<u>Unfiltered, Treated (5 ml. HNO_3/L)</u>
	Radioactivity
	Hg
	Se

The following determinations will be made and recorded for each sample in the field:

(1) Temperature
(2) pH
(3) Dissolved Oxygen
(4) Specific Conductance

Each sample will have the following information recorded:

(1) Identification number
(2) Location of sample
(3) Date and Time of Day
(4) Person taking sample
(5) Any remarks as to characteristics of water

Samples will be carefully taken to avoid mixing with air. Clean polyethylene bottles will be filled from the bottom up, with a tube extending to near the base of the bottle at a low rate to avoid turbulence. At least two container volumes will be allowed to overflow, then the sides will be squeezed gently while capping to avoid trapping air in the bottle. All filtering will be performed in the existing lab on Tract to avoid any contamination of the samples in the field. Once per year duplicate samples will be analyzed by different laboratories as a check on the analytical procedures used. Reference samples will be run as required by the AOSO as part of this quality assurance program. To determine the inherent precision of the methods used for each component measured, analyses of "typical" water will be run 5 to 10 times on aliquots of the same sample to establish experimental standard deviations for each component. Assuming consistency of techniques, reported changes in subsequent analyses will be compared to these standard error estimates to distinguish between real changes in composition and inherent experimental error.

For field measurements of quantities such as pH, specific conductance, and DO the field instruments will be calibrated, following the instrument manufacturer's recommended procedures, immediately before each series of measurements and these calibration records will be filed for future reference. Twice a year, the instruments will be checked against "absolute" standards for a range of values in the Grand Junction Lab.

5.6.2 Water Level Measurements

Head measurements will be checked for internal consistency by calibrating conductance probe measurements against Stevens recorder measurements each time the probes are used in wells which do not have recorders. An additional check on head measurements in the deep aquifer wells is to run static gradient surveys once per year by an independent cable tool company which uses Amerada gauges. These gauges can provide a check on head measurements.

Beside the inherent types of errors, there is the problem of gross errors in reading and recording results, and transcribing them to final form. Hence each new set of data will be compared to previous ones both by technicians in the field making the measurements and by the person responsible for assembly and reporting the data. Any apparent anomalies - such as a sudden reversal of a trend - will be checked by repeated measurements. All final data reports will be checked against original, hand-written field records. All field record forms are designed to minimize the chance of recording error. Finally, once per year, an entire series of measurements and sampling procedures will be reviewed with the technicians to see if any procedural changes are required to minimize error.

6.0 AIR QUALITY AND METEOROLOGY

6.1 Introduction and Scope

Volume 3, Meteorology, Air Quality and Noise of the Final Report of the Environmental Baseline Program contains a chapter called Program Utilization whose primary purpose is to serve as a guideline to the Development Monitoring Program. The present report utilizes material from the above reference; the interested reader should consult it for more complete discussion on background and guidelines.

As discussed in the Introduction, the Development Monitoring Program consists of three monitoring categories; basic, development-related, and systems dependent. As applied to air quality, basic monitoring consists of ambient monitoring, i.e., monitoring of surrounding conditions for both gaseous atmospheric constituents and total suspended particulates, along with supporting meteorology. Area-wide visibility is another major element of basic monitoring. The prime monitoring constituents in the development-related category concern a) source emissions from stacks, vehicles and shale piles, and b) air diffusion modeling validation. The systems dependent category includes "triggering" of additional air-quality stations or increased sampling frequency or incorporation of additional monitoring elements (such as trace elements in stack gases) - examples only - as a result of unexpected levels or trends in the basic indicator variables depicted on Table A-1.

Because of the extended time period that the Development Monitoring Program covers and the changing development and operational phases, air quality monitoring must be regarded as dynamic. Number and location of sites, quantities sampled, sampling techniques, and sampling frequencies are subject to change with time inasmuch as it is a scientifically designed program, the results of which are subject to on-going analyses and cumulative judgments. This program attempts to address air quality impacts which are predicted before the fact and those which occur but weren't predicted.

6.2 Ambient Air Quality

Three categories of the ambient air quality include monitoring of gaseous constituents, particulates, and area-wide visibility.

6.2.1 Gaseous Constituents

6.2.1.1 Objectives and Rationale

Objectives of the ambient air-quality program include:

a) provisions of a general air-quality status assessment;

b) demonstration of compliance with air-quality regulations and standards and with the lease;

c) establishment of long term air-quality trends from baseline, if any;

d) monitoring of hazardous constituents specified in State or Federal regulations for which a potential source has been identified;

e) attempt to establish sources for high background measurements.

Constituents to be measured include:

Sulfur dioxide
Nitrogen dioxide
Carbon monoxide
Ozone

which are designated the so-called "criteria" pollutants whose monitoring is required under the National Ambient Air Quality Standards; samples and/or averaging times are consistent with these requirements (objective b). Additional parameters measured include:

Hydrogen sulfide
Oxides of nitrogen
Nitric oxide

All of the above measurements have been required by the AOSO under the Lease Stipulations. For example, Lease Stipulation 1(C)1 states that conditions prior to, during, and subsequent to development operations be monitored as well as a record of changes (trends) and demonstration of compliance with State and Federal regulations. Thus all the objectives are consistent with these. Regarding hazardous constituents, air quality requirements are contained in State and Federal Emission Standards for Hazarous Air Pollutants. Of the substances covered under those standards, only Hydrogen Sulfide has any potential for measurable ambient concentrations at C-b, and it is being continuously monitored. Where a hazardous constituent required to be monitored exists as particulate matter, it will be monitored as particulate.

Achievement of objectives a and d are obtained by direct measurements. Objective b is accomplished by sampling and/or averaging consistent with regulations requirements (and comparing with the values of the standards). Long term trends (objective c) may be attained by utilizing identical station locations over extended time periods. Objective e is attained by correlation of appropriate gaseous concentrations with each other (e.g. SO_2 with H_2S) and with wind speed and direction measurements.

6.2.1.2 Methods

Methods of sampling ambient gaseous constituents utilizing continuous recorders are as follows:

Constituent	Technique
SO_2	Flame photometric
H_2S	" "
NO_x	Chemiluminescent
NO	"
NO_2	NO_x - NO
O_3	Chemiluminescent
CO	Non-dispersive infrared

It is expected that, in addition to these ongoing measurements, special studies will take place from time to time. High readings of hydrocarbons and ozone, presumed to be primarily from natural causes, have occurred at the Tract. One such study planned for the summer of 1979 is a hydrocarbon grab-sample study.

6.2.1.3 Experimental Design and Data Analysis

The air quality network is shown on Figure 6.2-1. Air quality trailers which contain samplers for the gaseous constituents are currently located at Stations 020, 023, & 024. Baseline Stations 021 and 022 are discontinued. Parameters monitored are shown on Table 6.2-1 at sampling and reporting frequencies shown on Table 6.2-2; minimum data reporting frequency consists of 1-hour averages. One-, three-, eight- and 24-hour averages will continue to be computed as necessary for comparison with standards (objective b). It is to be noted that compliance is required (NAAQS) both on and off Tract so that multiple stations are a necessity.

Station location and timing rationale are as follows: Station 023 and the meteorological tower have been in continuous operation since the start of the environmental baseline in November 1974 and thus provide long term trend information (objective c). Air-quality parameters monitored at that station include SO_2, H_2S, particulates, O_3, NO_x, NO, NO_2, and CO. Station 023 is the most heavily instrumented trailer in that it is co-located with the 60-meter meteorological tower and contains all tower data channels. During the ancillary phase it is expected to provide data under pristine conditions inasmuch as it is upwind of development for the prevailing south-southwesterly winds.

However, in a meteorological sense, no air quality station can be upwind of development for all possible wind directions, therefore no one station can be solely regarded as either a "control" or solely as a "development" site. Therefore, as development of the commercial operations proceeds its adequacy

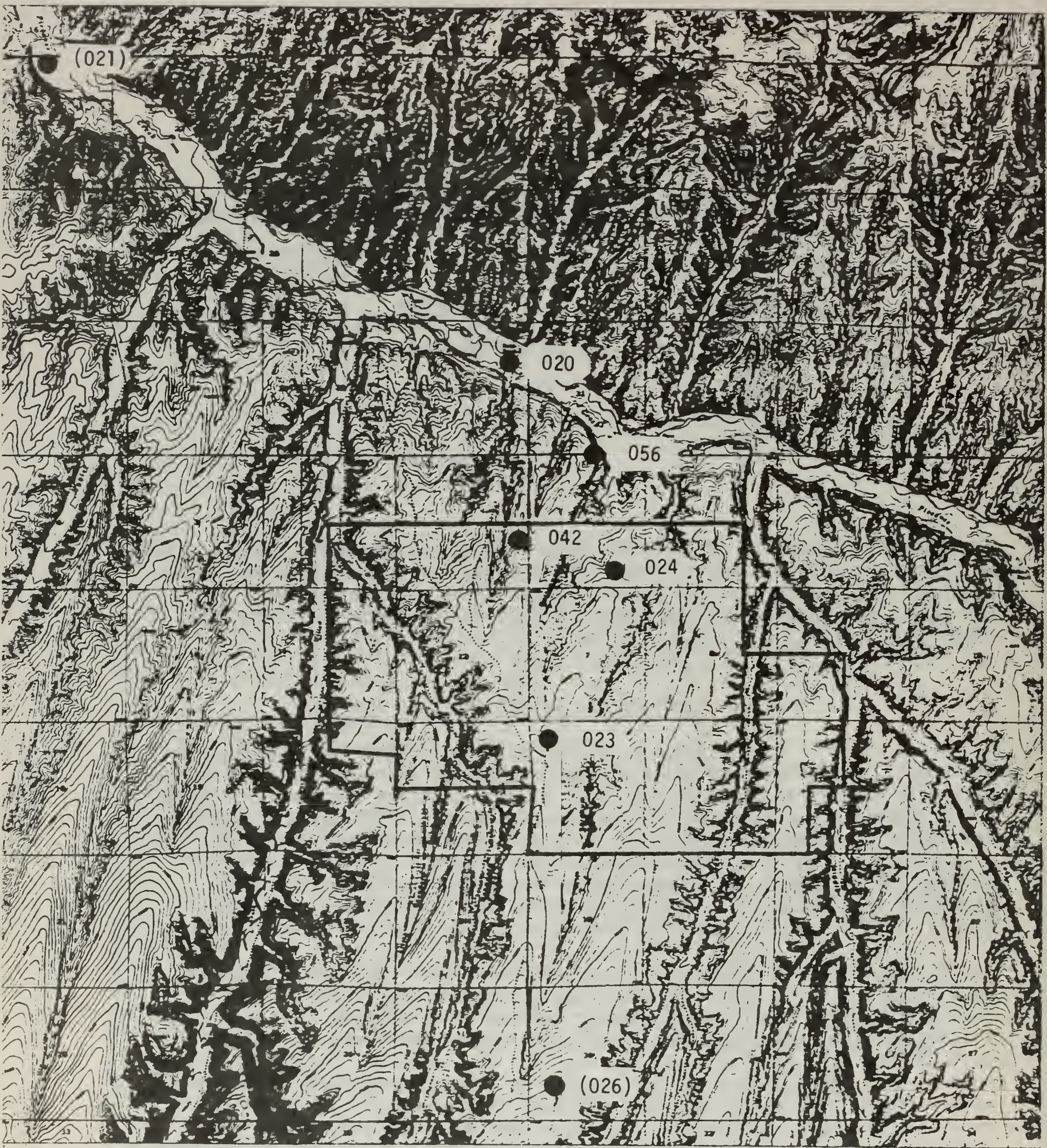


Figure 6.2-1
AMBIENT AIR QUALITY DEVELOPMENT MONITORING NETWORK

Note: ( ) = Systems Dependent

TABLE 6.2-1

AMBIENT AIR-QUALITY & METEOROLOGY DATA DESCRIPTION

Symbols represent sampling frequency on Table 6.2-2

Measurement: Category and Location	Start-up Date	SO_2	H_2S	Particulates (3)	Ozone	NO_x	NO	NO_2 (1)	CO	Horizontal Wind Speed	Horizontal (2) Wind Direction	Vertical (2) Wind Speed	Relative Humidity	Air Temperature	Precipitation (4)	Evaporation	Barometric Pressure	Solar Radiation	Temperature Difference	Mixing Height	Visible Range	Height	SF_6
Air-Quality Trailer																							
020	a) Jan. '78			0						X	X				Z								
	b) July '78				X	X	X	X	Y					X									
	c) 1980	X	X																				
021	Systems Dependent																						
023	Nov. '74	X	X	0	X	X	X	X	Y						Z	S	X	X					
024	a) 1980			0						X	X			X									
	b) 1981	X	X																				
026	Systems Dependent																						
Weather Sta & Hi-Vol Sampler																							
042	Feb. '78			0						Z	Z			Z									
056	Feb. '78			0						Z	Z			Z									
Met. Tower @																							
3m	Nov. '74												X*										
10m	Nov. '74									X	X	X		X					2				
30m	Nov. '74									X	X			X									
60m	Nov. '74									X	X	X		X					2				
Upper Air Studies																							
Minisonde	Oct. '77									W	W			W								W	
Acous. Sound, 020	Oct. '77																			U		U	
Visibility, Sta. 060	Apr. '78																				V		
Tracer Studies	Fall '78																						T

* @ 1m

(1) $(NO_2) = (NO_x) - (NO)$
(2) Std. Deviation calculated.
(3) Also Size Distributions during Visibility Study
(4) These stations also used to obtain waterquality of ppt. measurements as indicated in Chapter 5.

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TABLE 6.2-2

ABMIENT AIR QUALITY AND METEOROLOGY SAMPLING AND REPORTING FREQUENCIES

Symbols appear on Table 6.2-1

Symbol	Sampling Frequency	Minimum Average Time	Minimum Report Frequency	Description
X	10-seconds	5-minutes	1-hour	AQ & Low Alt. Meteorology
Y	5-minutes	5-minutes	1-hour	AQ & Low Alt. Meteorology
Z	Continuous	1-hour	1-hour	Precipitation
O	Every 3rd day	24-hours	24-hours every 3rd day	Particulates
2	20-seconds	5-minutes	1-hour	Temp. difference from 10-meter to 60-meter on Met. Tower
W	Approx. 30-seconds	Approx. 30-seconds	Approx. 30-seconds	Double Theodolite Minisonde
U	14-seconds		1-hour	Inversion Height/Mixing Layer from Acoustic Sounder
V	7 times per day every 6th day for 20 days in Spring and 20 days in Fall	Hourly	Daily (w/hourly max/min.)	Joint Visibility study with C-a from Hunter Creek Site
T	Continuous for approx. 2 days	1-hour	1-hour	SF_6 Tracer Studies for Air Diffusion Model Validation
S	Weekly	Weekly	Weekly	Evaporation

as a "control" station will be re-examined. Then Station 026 may be established as a "control" station in the event that nearby development appeared to impact 023; identical parameters would be monitored in parallel for a period of time. Station 026, at present is to be regarded as "systems dependent," however. Instrumentation accuracy is verified at Station 023 by continuing EPA near-quarterly audits.

Station 020 is planned to be reactivated according to the schedule shown on Table 6.2-1. Particulates came in line in January 1978. Non-sulfur instruments were re-activated in July 1978. Sulfur measurements (SO_2, H_2S) will be re-activated prior to kindling of the first ancillary retorts. Station 020 is generally downwind from the Tract so will be exposed to particulate loadings (fugitive dust) during construction. It is near the estimated off-tract point of maximum pollutant concentration during both ancillary and commercial phases under conditions of F stability where the air flow from the Tract is subsequently constrained by the Piceance Valley walls. During the manpower peak associated with construction, Station 020 is expected to be exposed to relatively heavy concentrations of pollutants from vehicular exhaust in the main Piceance Creek access corridor. Thus in one sense, Station 020 is the "development" or "treatment" site and Station 023 is the "control" under prevailing winds.

Station 024 on Tract on the ridge east of Cottonwood Gulch comes on line in 1980 for measurement of fugitive dust associated primarily with shale pile disposal. Prior to kindling the ancillary retorts sulfur instruments are initiated. Station 024 is also expected to be near the on-tract point of maximum pollutant concentrations for the A-Stability case during the operational phase.

Station 042 and 056 are particulates sampling stations (hi-vols) which became operational in February 1978 primarily to monitor dust from construction and shale pile disposal.

It is to be noted that air quality stations are subject to relocation, pending the outcome of development and application of an adequate rough terrain diffusion model which yields pollutant concentration isopleths. Thus it will define more clearly the expected point(s) of maximum ground-level concentrations which have only preliminarily been estimated by a "screening" diffusion model to date.

A quality assurance plan* has been prepared for the C-b Tract and is being implemented. Copies of this document have been furnished to the EPA and the

*Quality Assurance Plan for Air Resources Monitoring, Oil Shale Lease Tract C-b by AeroVironment, Inc., 145 Vista Avenue, Pasadena, California, November 1977 plus revisions.

Air Pollution Control Division of the State of Colorado Department of Health. It covers monitoring site selection, monitoring equipment and procedure, data reporting, data validation, calibration, station checks, preventative maintenance, audits/interlaboratory tests, spare provisions policy, and training.

Data analysis techniques have been summarized on the matrices given on Table 6.2-3. This table presents each study, title and purpose, number of sampling stations, sampling frequency, reporting interval, sample definition, calculations, sample size, spatial comparisons to be made, temporal comparisons, parameters compared, hypotheses tested, analytical techniques used, level of significance, and graphic parameters.

The analyses indicated to be done by Table 6.2-3 not only vary with the objective, but with the constituent measured. For example, at least to the present time, H_2S, SO_2, the oxides of nitrogen, and CO have been at or near the minimum detectable limit of the instruments; extensive analysis for such cases is not warranted. Only for ozone and particulates have background values been consistently away from zero values.

To demonstrate compliance with regulations the number of "exceedances" and date each month (if any) by constituent will be tabulated; actual peaks will be listed by month for averaging times consistent with standards. To establish potential long-term trends over time the following hypothesis will be tested:

H_0: Monthly and annual means do not change over time.

Time series analysis at a 95% level of confidence will be used for monthly means; for ozone this will entail that of Box-Jenkins; for other parameters, a graphical analysis is envisioned; annual regression lines will be used for annual means (90% confidence). To test the hypothesis that monthly means do not change between stations over time, the differences in monthly means will be plotted as time histories. To identify potential emissions sources 3D plots of hourly concentration as functions of wind speed and direction, as utilized during baseline, are planned. The reader should consult Table 6.2-3 for detailed planned analyses corresponding to each objective.

It is expected that, from time to time, special analyses, some yet undefined, will be undertaken. These are not shown on Table 6.2-3. Some of these include:

1) Ozone - high ozone levels from natural causes have infrequently occurred, analysis of future occurrences is planned including correlation with meteorological parameters.

2) Analysis of hydrocarbon grab samples will be undertaken. When such sampling occurs, such sampling will have prior concurrence of the AOSO.

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Table 6.2-3

Air Quality
Data Analysis Matrix

Rev. 1- 1/22/79

NUMBER	STUDY TITLE	PURPOSE	NUMBER OF STATIONS	SAMPLING FREQUENCY	REPORTING INTERVAL	SAMPLE DEFINITION	CALCULATIONS	NUMBER	SAMPLE SIZE	COMPARISONS SPATIAL	COMPARISONS TEMPORAL	PARAMETER COMPARED	HYPOTHESES TESTED	ANALYTICAL* TECHNIQUES USED	TEST LEVEL OF SIGNIFICANCE	GRAPHIC PARAMETERS
6.2.1	GASEOUS CONSTITUENTS	a) Demonstrate compliance with regulations.	THREE: 2 Sta. monitoring 7 constituents each, plus 1 sta. monitoring 2 constituents.	CONTINUOUS	Hourly in monthly diurnal tables.	Continuous monitoring of concentrations in ppb reduced to 5-min averages and then to hourly averages for each constituent. Additional averages as follows SO_2, 3-Hr & 24-Hr; CO, 8-Hr; H_2S, 24-Hr.	5-min averages from 10-sec. scans hourly averages from 5-min averages, sliding hourly averages, annual means (arithmetic) from 24-Hr. averages for SO_2, NO_2, and H_2S.	6.2.1	By month: 3-Hr & 24-Hr SO_2, 1-Hr & 8-Hr CO, 1-Hr O_3, 24-Hr H_2S; Annual SO_2 & NO_2.	None	No. of exceedances for each mo. by pollutant, list numerical value of the max exceedance, list peak numerical values.	None.	NA	A	NA	None.
		b) Examine potential long-term trends from baseline. Air Quality status assessment.	THREE: 2 Sta. monitoring 7 constituents each, plus 1 sta. monitoring 2 constituents.	CONTINUOUS	Hourly in monthly diurnal tables.	Hourly averages.	Daily and monthly averages from baseline and thereafter		Daily and monthly mean and peak values for each gas above min. detectable limit, annual means for SO_2, NO_2, CO.	None.	Daily and monthly time series, annual regression.	None.	Monthly & annual means do not change over time.	A,B,C,M for 7 gases; C,E,G,H,K for O_3.	95% Confidence (monthly); 90% (annual).	Daily time histories of means and peaks
		c) Quality status assessment.	THREE: 2 Sta. monitoring 7 constituents each, plus 1 sta. monitoring 2 constituents.	CONTINUOUS	Hourly in monthly diurnal tables	Hourly averages.	Compute daily and monthly averages.		Daily and monthly mean values for each quarter.	Between stations at specified times.	None.	Daily means from 2 sta	Daily means do not change between sta.	H,I for O_3.	95% Confidence Interval for coef. of correlation.	Time histories of differences
		d) Identification of potential sources	THREE. 2 Sta. monitoring 7 constituents each, plus 1 sta. monitoring 2 constituents.	CONTINUOUS	Hourly in monthly diurnal tables	Hourly concentrations for the quarter for each constituent.	Bivariate frequency distributions of 1-hour concentrations by wind speed and direction by station.		3 months of hourly values	Station to station.	None	SO_2 vs H_2S, when significantly above detectable limits.	Hourly differences do not change over time for given station.	C,H,I,K for O_3.	95% Confidence interval for coef. of correlation.	3 D Plots, when shown to be significant
6.2.2	PARTICULATES	a) Demonstrate compliance with regulations.	FIVE: 3 Sta. same as in 6.2.1 + 2 additional stations	Once every 3 days.	24-Hour in Monthly Tables.	One 24-Hr average every 3rd day.	Annual means (both arithmetic and geometric) from 24-Hr averages.	6.2.2	By month: 24-Hr values.	None.	No. of exceedances & numercial value of peak; peak monthly value.	None.	NA	A	NA	None.
		b) Examine potential long-term trends from baseline; Air Quality status assessment.	FIVE: 3 Sta. same as in 6.2.1 + 2 additional stations.	Once every 3 days.	24-Hour in Monthly Tables.	One 24-Hr average every 3rd day.	Monthly averages.		Daily and monthly means and peaks, annual geometric means.	None.	Daily and monthly time series; annual regression.	None.	Monthly and annual means do not change between sta. with time.	B,C,E,F,G,H,I,K,M	95% Confidence (monthly); 90% (annual).	Time histories of daily means and peaks.
		c) Provision for a general Air Quality status assessment.	FIVE: 3 Sta. same as in 6.2.1 + 2 additional stations.	Once every 3 days.	24-Hour in Monthly Tables	One 24-Hr average every 3rd day	Monthly averages.		Daily and monthly means for each quarter.	Between stations at specified times	None.	Daily totals for 4 sta.	Daily totals do not change between sta.	H,I	95% Conf (mo.); 90% (annual).	Time histories of differences when significant.
		d) Identification of potential sources.	FIVE: 3 Sta same as in 6.2.1 + 2 additional stations.	Once every 3 days.	24-Hour in Monthly Tables	24-Hr concentrations for the quarter.	Bivariate frequency distributions of 24-Hr concentrations by wind speed & direction by station.		3 months of 24-Hr values (every 3rd day).	Station to station	None.	None.	NA	C,H,I,K	95% Conf.	3 D Plots.
6.2.3	AREA-WIDE VISIBILITY	To establish long-term trends in visual range in comparison with the baseline period.	One station at Hunter Creek Site.	7 Times/Day, every 6th day for 20 days; Semi-Annually.	Daily.	Visual range 7 times a day, every 6th day for 20 days in Spring and 20 days in Fall.	Hourly maximums and minimums by day, calculate visual range, means & std. dev. by variable.	6.2.3	Four views obtained 7 times per day during study. Visual range (VR) measured in miles.	Comparisons by view.	Visibility comparisons by view and over all views vs time (months).	Selected monthly means by view.	No annual change in selected monthly means.	B,F,H,I,K	NA	Frequency of occurrence vs VR by view by season. VR vs time by view.
6.3.1	CLIMATOLOGICAL RECORDS	To establish long-term trends in temperature (T), Relative Humidity (RH), Precipitation (P), and Evaporation (E), Barometric Pressure (BP), and Solar Radiation (SR).	Four stations (one of them with 3 levels) & acoustic sounder.	Continuous for all except (E)(weekly).	Hourly (Weekly for E).	Continuous monitoring for 6 parameters reduced to 1-Hr averages.	Means (totals to P) by week and month. Daily extrema by month for RH, BP, & SR.	6.3.1	T in °F at all sta and levels; ΔT in °F on Met Tower at 10m and 60m; RH in % at 2 sta, P in .01" at 2 sta; E at 1 sta in .01"; BP in mb at 2 sta; SR in cal/cm² at 1 sta.	Precipitation at 020 vs precipitation at 023.	All parameters vs Time.	NA	No change in means over time.	B,G,H,I,K	95% conf.	Daily time series.
6.3.2	WIND FIELDS	To establish long-term and seasonal trends in wind flow over Tract C-b.	4 stations (one of them with 4 levels) + minisonde. 2 Parameters at all stations and levels + 3 other parameters at 1 sta (2 levels).	CONTINUOUS	Hourly in monthly diurnal tables.	Continuous monitoring reduced to 5-min and then hourly vector averages & std. dev. by wind field parameter (WS, WD).	5-min averages from 10-sec values, hourly averages from 5-min averages, frequency of occurrence of 1-Hr averages.	6.3.2	A 1-Hr average.	Station vs station.	Parameter vs time	Wind speed, & direction.	NA	B,D,H,I,J,K	95% Conf	% Frequency dist. Direction only wind roses at 10m by month. Vector wind roses at 30m using 1-Hr averages by quarter & year.
	AND								AND							
	MODELING SUPPORT	To provide information to support and validate air diffusion modeling.	Three methods of measurement: 1) Acoustic Radar 2) Minisonde 3) Tracer Studies	1) CONTINUOUS 2) CONTINUOUS 3) 3 Day Test.	1. Hourly. 2. Hourly. 3. 1-Hour	Continuous monitoring reduced to reporting interval averages of HWS & HWD. Temp., Mixing ht, Inversion Top, and SF_6 concentrations.	1. Hourly averages, frequency of occurrence. 2. Hourly averages. 3. 3-Hr., 24-Hr averages.		A 1-Hr average of parameter according to method used.	None.	None.	NA	NA	D,J,L	NA	Mean early morning, afternoon mixing layer hts., by month vs time.
6.4.1	EMISSIONS MONITORING	To comply with EPA - PSD Permit and EPA new source performance standards (none at this time) with CoTo. SIP's and AOSO.	Eight monitoring points - See Table 6.4-1.	Intermittant	To Be Determined.	Mon. of 15 parameter groups among 8 mon. points as follows (Hg-As-Se-Arsine) 2pts. $(SO_2)@_4$, $(H_2S)@_2$, $(Part)@_6$; $(CS_2)@_2$; $(COS)@_2$, $(RSH)@_2$, $(NO_x)@1$; $(O_2)@1$; $(CO_2)@1$; $(CO)@_1$; flow rate $@_2$; $(Temp)@_2$, $(Moisture)@_2$; and $(Opacity)@_6$. See Table 6.4-1.	Means and standard deviations by day. lb/hr emissions for SO_2 and particulates.	6.4.1	15 Parameter groups measured at 8 monitoring points.	NA	NA	NA	NA	NA	NA	TBD
6.4.2	AIR DIFFUSION MODEL VALIDATION	To provide continuing validation for the atmospheric diffusion model.	23-29 3 AQ Trailers + SF_6 tracer receptors	Continuous for 3 days per year.	Hourly.	Continuous 1-Hr concentration of SF_6 from 20-26 automatic sequential syringe samplers.	Atmospheric diffusion coefficients calculated for each sample at each station.	6.4.2	Five consecutive 1-Hr concentrations in μg/m³	Ground-level concentration in μg/m³.	Concentrations between samples at each station.	S	NA	GOAL. Ground level 1-hour-average concentrations as measured values and as predicted by the model shall, through regression analysis, demonstrate a coefficient of correlation of at least 0.8.	NA	Isopleths of ground level concentrations.

DEFINITIONS.

- CAL/CM²: Calories per square centimeter
- CFR Code of the Federal Register
- COS Carbonyl Sulfide
- CS_2: Carbon Disulfide
- HWD Horizontal Wind Direction
- HWS Horizontal Wind Speed
- NA: Not Applicable
- PPB: Parts per billion
- PSD: Prevention of Significant Deterioration
- RSH An organo-sulfur compound
- SF_6 sulfur hexafluoride

*ANALYSIS CODES

- A. Number and date of excursions beyond ambient standards
- B Time Series plots (daily mean, min., and max. or total as applicable)
- C. 3 dimensional plots (Quarterly and Annual means or totals)
- D. Wind Roses (Quarterly and Annual)
- E. Concentration Roses (Quarterly and Annual)
- F Histograms
- G Time Series Analyses (Box-Jenkins Techniques applied to monthly averages)
- H Correlation between stations and/or parameters
- I Regression analyses including calculation of X, s, and r^2 (As dependent variable with time and/or other independent variables)
- J. Stability class.
- K. Special studies.
- L. Diffusion modeling
- M. Data uncertainty analysis

6.2.2 Particulates

6.2.2.1 Objectives and Rationale

The objectives for partiulcate measurement are identical to those for gaseous constituents a - c, e (Section 6.2.1.1). In addition it may be possible to estimate fugitive dust emission factors from particulate samplers downwind of shale piles. Regarding objective d, shortly before and during retorting, particulate analyses for trace elements will be done to comply with State and Federal regulations.

Total suspended particulate measurements are required under the NAAQS for 24-hour and annual averaging times.

6.2.2.2 Methods

Hi-vol samplers are used to obtain one 24-hour sample every third day. Filters are stored for approximately 6 months, pending the need for possible chemical analyses and then discarded. During visibility studies, particulate size distributions are obtained via Anderson sampler or equivalent techniques.

6.2.2.3 Experimental Design and Data Analysis

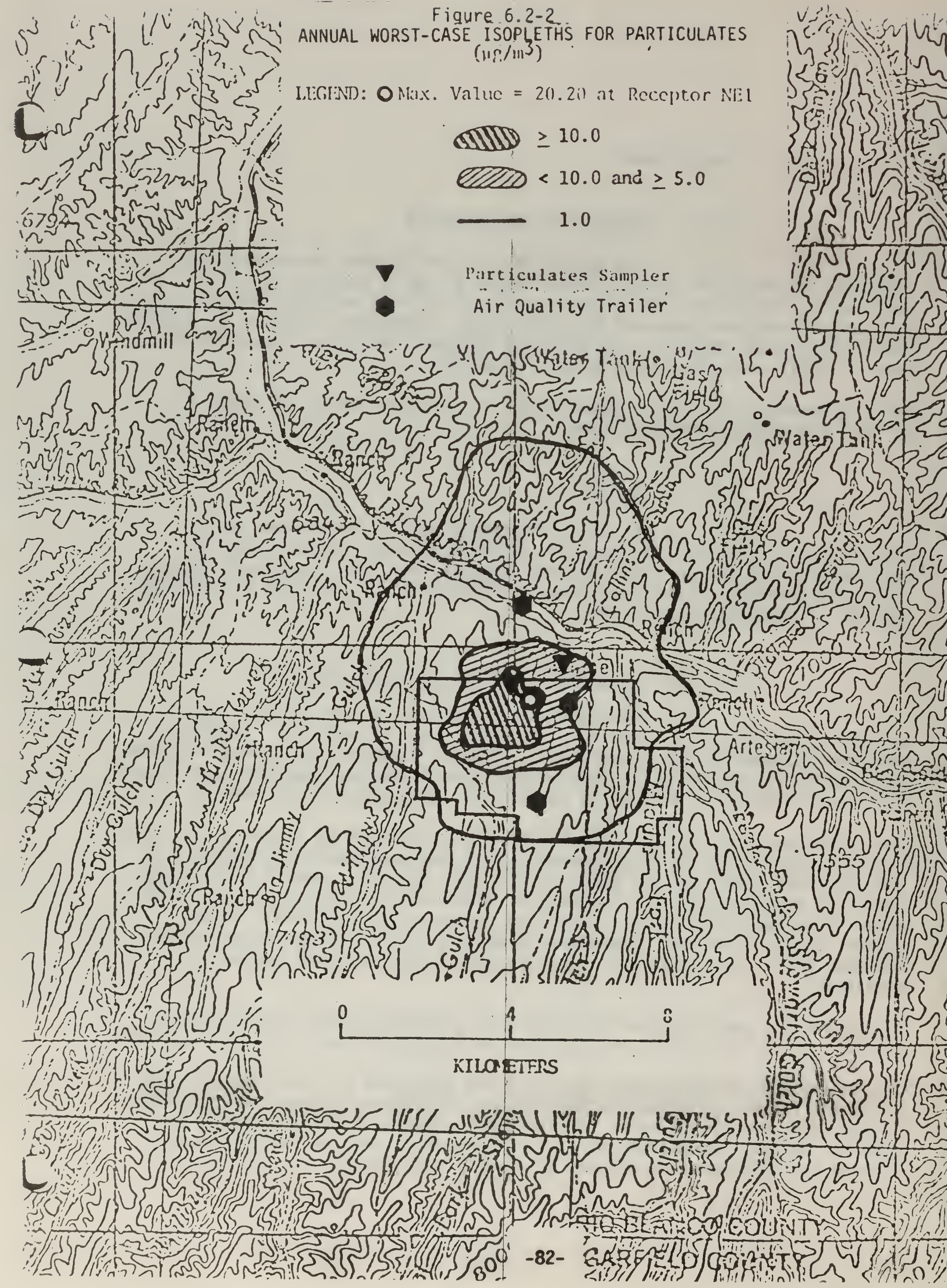
The particulate sampling network (Figure 6.2-1) currently consists of 5 stations: 020, 023, 024, 042 and 056. Baseline stations 021 and 022 are discontinued. Station location and timing rationale was covered in Section 6.2.1.3 for compactness. Station locations are subject to change pending new monitoring results and development requirements.

The "reasonableness" of the present network is depicted on Figure 6.2-2. This figure presents results from previous air diffusion (screening) modeling of the ancillary phase for all point and fugitive sources. Annual particulates isopleths are presented for incremental values of 10, 5 and 1 $\mu g/m^3$ with 80 acres of unrevegetated shale. Sampling stations fall within all three contour levels. Contours are approximate only, and are expected to change somewhat when a site-specific, rough-terrain diffusion model becomes available.

The previously mentioned quality assurance program applied to particulates monitoring; the EPA audits particulates at Station 023 approximately quarterly.

The analyses to be undertaken vary with the objective as indicated on Table 6.2-3 and include plotting, regression and correlation, histograms, and Box-Jenkens time series analysis. To identify potential emission sources 3D plots of 24-hour concentrations as functions wind speed and direction are planned providing wind dependency is clearly indicated.

Figure 6.2-2
ANNUAL WORST-CASE ISOPLETHS FOR PARTICULATES
($\mu g/m^3$)



Particulate size distribution analyses (a special study not shown on Table 6.2-3) are to be correlated with particulate concentrations and other relevant parameters through multiple regressions.

6.2.3 Area-Wide Visibility

6.2.3.1 Objectives and Rationale

Objectives of the visibility program are to:

a) assess area-wide visibility in the Piceance Basin;

b) establish long-term trends from baseline, if any.

c) demonstrate compliance with Federal visibility regulations as they are promulgated.

This program is conducted to satisfy general requirements of the Environmental Lease Stipulations, and the requirements of the Clean Air Act of 1977. Regulations related to the latter are, as yet, not promulgated by the EPA. This program, therefore, may be subject to change.

Visibility is a good indicator of purity of the air; it is probably the most frequently used layman tool for assessing air quality and the only parameter easily understood or recognized by the general public.

6.2.3.2 Methods

The currently used technique of photographic photometry utilizes Steffan's method where visual range (VR) is obtained from:

$$VR = Mx/\ln(1-I_x/I_\infty)$$

where

M = const = 3.912
x = distance of object from camera
I_x = light intensity of object x
I_∞ = light intensity of horizon sky
$\frac{I_x}{I_\infty} = \frac{E_x}{E_\infty} = 10^{D_x - D_\infty}$
E_x = film exposure of object x
E_∞ = film exposure of horizon sky
D_x = image density of object x on the film negative
D_∞ = image density of the horizon sky on the same film negative.

The above equation assumes that the object is black; it is modified slightly to account for non-black objects.

In the Fall 1978 test period, a side-by-side test was initiated whereby a telephotometer was utilized alongside the present photometer to obtain a set of correlated measurements. If a satisfactory correlation is obtained, only the telephotometer will be used for 1979 and thereafter.

Visual range from the Gamma Scientific Inc. autotelephotometer, model 2009, is obtained from the identical equation except that the light intensity no longer needs to be related to a film exposure. The telephotometer measures light intensity directly in footlamberts.

6.2.3.3 Experimental Design and Data Analysis

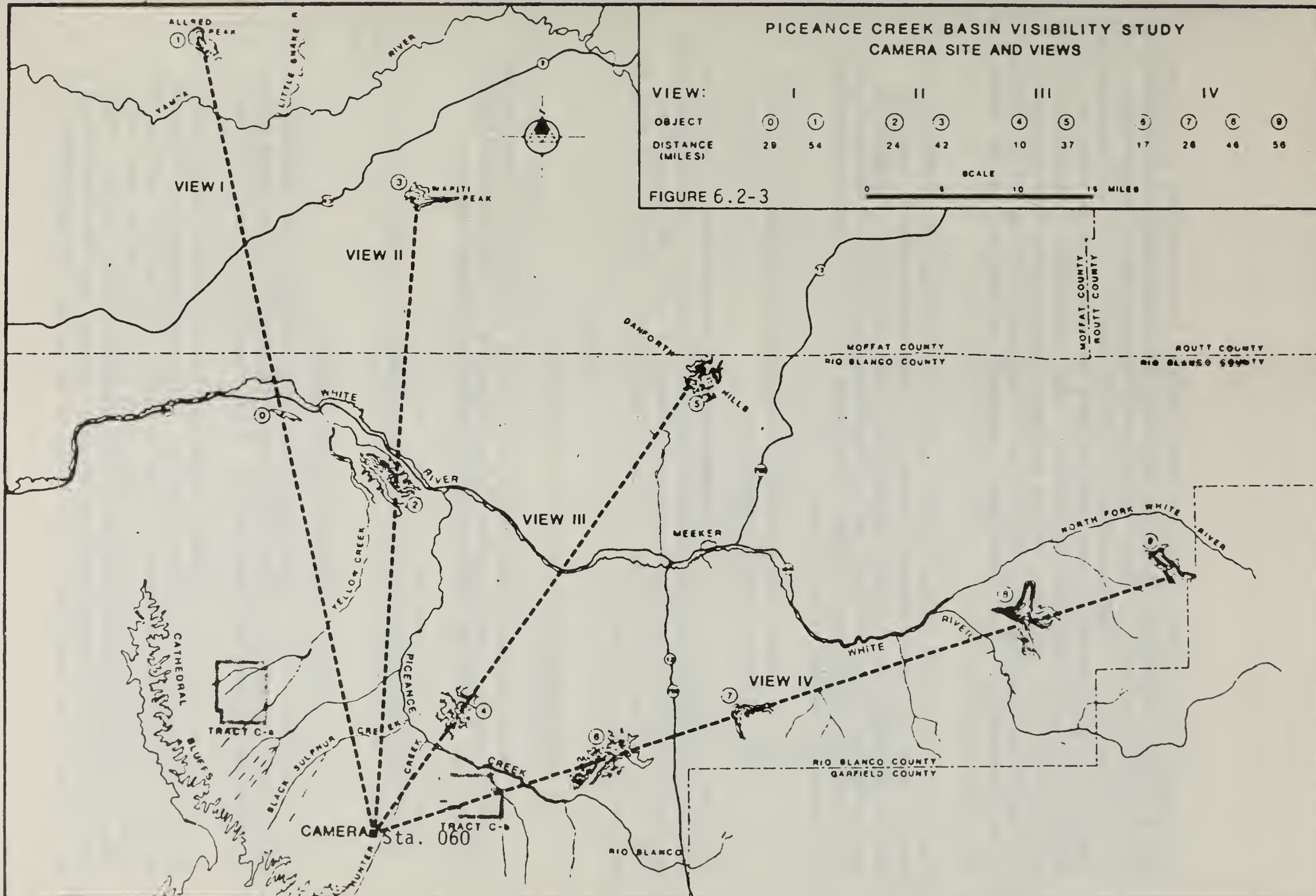
The existing site in Hunter Creek utilized in baseline is presented in Figure 6.2-3 showing the four views and siting objects per view. Visual range measurements in each view are to be made every sixth day for a total of 20 days in Spring and in Fall at nominal hours of 0830, 0930, 1030, 1130, 1300, 1400 and 1500 MST. Visual range is reported as daily, monthly and seasonal averages both in each of four views and as averages summed over all views.

The photographic measurements of visual range are accomplished with a 35 mm camera attached to an 800 mm refractive lens. Black and white panchromatic film is used to photograph the objects in each view at prescribed hours every sixth day. In addition, color slides are taken concurrently with a normal focal-length lens and 35 mm camera to pictorially record the sky and weather conditions in each view.

Regarding quality control for photographic photometry, processing of the black and white film is to be accomplished under closely controlled conditions. Photographic chemicals are frequently replaced and processing temperatures held to within ± 1^{o}C. Color film is not used to provide numerical data; thus it is developed through commercial sources.

Prior to development of the black and white film, the leading end of each film roll is exposed to a calibrated series of eleven different light intensities. Each film roll is exposed to these light intensities in a Kodak Process Control Sensitometer Model 101.

Once development of the film roll is complete, the densities of the eleven steps, referred to as a sensitometric strip, are obtained with a MacBeth TD504 Densitometer. The sensitometer used to obtain the sensitometric strip is factory calibrated and its light source is replaced at the manufacturer's recommended intervals. The densitometer calibrated before and after reading each film roll, exhibits a repeatability of ± 0.01 density units. These densities, when plotted versus the logarithm of the exposure, provide a characteristic curve for each particular film roll. The characteristic curve provides the functional relation between exposure and image density.



PICEANCE CREEK BASIN VISIBILITY STUDY
CAMERA SITE AND VIEWS
VIEW: I II III IV
OBJECT 0 1 2 3 4 5 6 7 8 9
DISTANCE (MILES) 29 54 24 42 10 37 17 28 46 56
SCALE
0 5 10 15 MILES
ALLRED PEAK
WAPITI PEAK
YAMPA
RIVER
LITTLE SNAKE R.
VIEW I
VIEW II
VIEW III
VIEW IV
DANFORTH HILLS
MOFFAT COUNTY
RIO BLANCO COUNTY
ROUTT COUNTY
WHITE RIVER
YELLOW CREEK
MEEKER
NORTH FORK WHITE RIVER
CATHEDRAL BLUFFS
TRACT C-a
TRACT C-b
BLACK SULPHUR CREEK
PICEANCE CREEK
HUNTER
RIO BLANCO
GARFIELD COUNTY
CAMERA
Sta. 060

FIGURE 6.2-3

Regarding quality control for the telephotometer, the instrument is equipped with a digital read-out in units of intensity (footlamberts). A calibration via a built-in calibration unit is made prior to each set of measurements. Each set consists of 3 measurements of target intensity and 3 of sky intensity (immediately above target) using the 6-minute aperture. Three values of visual range are computed and averaged; if one of the three is not close to the other two it is discarded in the average. Sky cover is indicated on the tabular data output as clear, 0.1 to 0.6 skycover, 0.6 to 0.9 or 0.9 to 1.0 as appropriate. This technique is identical to that used by the EPA at their Utah visibility site.

Item 6.2.3 of Table 6.2-3details the analysis techniques for visibility. Monthly means will be compared by view with each other and with baseline. Time series analysis of visual range measurements will be performed after every seasonal set of observations to determine any potential degradations in visibility. Histograms similar to baseline will continue to be displayed. The hypothesis tested is as follows:

H_0: No annual change exists in selected monthly mean values of visual range.

Additional analysis previously mentioned includes measurement of particle-size distributions during the period of visibility tests. Size distributions, particulate loadings and other relevant parameters are to be correlated with visual range via multiple regression techniques. Filters will also be analyzed for SO_4 and NO_3.

6.3 Meteorology

Meteorological measurements are used to establish a climatological historical record, to define wind fields primarily to understand pollutant transport and to provide additional air-diffusion modeling support.

6.3.1 Climatological Historical Records

6.3.1.1 Objectives and Rationale

The objective of this program is to establish a historical climatological data base to be utilized in its own right and to serve as the abiotic interface with the biotic portion of the ecosystem.

The justification for a long-term historical climatological record with regard to ecosystem interactions may be illustrated through the following example. It is very important in this endeavor to attempt to sort out the climatic effects on populations of important species found in the Tract from effects which might otherwise be attributable totally to man. How much a population fluctuates due to weather depends upon the interaction of two factors: the magnitude of fluctuations in weather and sensitivity of

the species to that degree of weather fluctuation. If weather fluctuates only a small amount and the species is insensitive to weather fluctuations, then this is the circumstance under which the relative importance of population-density-dependence as a regulatory mechanism will be maximal. The greater the sensitivity of the species to fluctuations, the more important population-density-independent mechanisms (e.g., weather fluctuations) will be in relation to density-dependent mechanisms in modifying trends in the species population. This complex problem requires observation of both climatology and of populations of species of local importance over an extended period of time to solve the relative importance of both contributing factors.

Parameters measured include:

Parameter	Instrument	Station
Air Temperature	Aspirated Temp. Sensor	020,023,024 042,056
Relative Humidity	R.H. Sensor	023
Barometric Pressure	Barometer	023
Solar Radiation	Pyranometer	023
Evaporation	Pan, anemometer, thermometer	023
Precipitation	Weighing-Bucket Gauge	020,023

6.3.1.2 Methods

Instrumentation has been summarized on the above table at the stations indicated.

6.3.1.3 Experimental Design and Data Analysis

Sampling and reporting frequencies are identical to the air quality parameters except that precipitation is continuously recorded and reported hourly, daily and monthly. Evaporation is sampled and reported weekly.

Regarding data analysis, spatial comparisons in precipitation between 020 and 023 will be made. Precipitation, barometric pressure, solar radiation, relative humidity, evaporation and temperature will be presented as functions of time as depicted in item 6.3.1 of Table 6.2-3. The experimental design for the supporting climatological parameters will be consistent with those ecosystem interrelationships with which they are to be correlated.

The hypothesis to be tested by time series analysis (95% confidence) is:

H_0: No change in monthly (mean) values exists from year to year (temperature, barometric pressure). Substitute (total) for precipitation.

The Box-Jenkens time series analyses utilized will determine stationarity over time; with seasonal effects removed stationarity indicates no long term climatic variations.

6.3.2 Wind Fields

6.3.2.1 Objectives and Rationale

The objectives of this program are a) to refine knowledge of the wind fields in the vicinity of the C-b Tract since they affect the transport and diffusion of pollutants, b) provide air quality support in that wind speed and direction at stations are needed as well as pollutant concentrations there, and c) to provide related information to be utilized as input to air diffusion models.

Flow patterns in rough terrain are non-uniform. Near surface flows in mountain-valley streams follow down-slope, down-valley courses at night and up-slope during daytime, constrained by valley walls. At elevations sufficiently far above the local terrain large-scale synoptic patterns exist. A plume, depending on its buoyancy, its release point and meteorological conditions can be affected by both local and large-scale effects. Diffusion models, to be relevant, become very site specific.

Parameters measured include:

Parameter	Instrument	Station
10-m horizontal wind speed	Anemometer	020,023,024,042,056
10-m horizontal wind direction	Vane	" " " " "
30-m, 60-m horizontal wind speed	Anemometer	Met Tower (023)
30-m, 60-m " " direction	Vane	" " "
60-m vertical wind speed	Sigma w meter	" " "
10,30 60-m horizontal wind dir. std. deviation*	Vane	" " "
60m vertical wind dir. std. deviation*	Sigma w meter	" " "
ΔTemp. (60m to 10m)	ΔT Sensor	" " "
Mixing layer height	Acoustic Radar	020
Winds aloft:		
Speed and Direction	Double theodolite,	024
Temperature	Temp. instrumented minisonde or pibal	024

*Computed quantities

Thus, with the above measurements the near-surface (10m) wind field is assessed at five stations.

The winds-aloft study is a joint C-b, EPA study conducted for a one year period (October 1977-78).

6.3.2.2 Methods

Instrumentation has been summarized in the above table at the stations indicated. Wind direction standard deviations have been computed as 5-minute averages from associated values of wind direction.

With regard to the objective of obtaining on-site data for input into mathematical models for the assessment of impacts of shale oil development, one of the mathematical parameters needed in the model is atmospheric stability at effective stack height. It is needed only for the determination of plume rise; it is not needed for the calculation of the dilution of emissions from the stack. Another parameter, namely, the degree of turbulence, is used to determine the dispersion of the plume. AeroVironment's model uses σ_θ, the RMS value of horizontal wind direction fluctuations, in calculating plume dispersion. This approach was recommended recently by the participants of the American Meteorological Society Workshop on Stability Classification Schemes and Sigma Curves (Hanna, et al, 1977).

The atmospheric stability at effective stack height should ideally be defined from the temperature lapse rate, which is used in equations derived by Briggs (1974), to calculate plume rise. There are basically two equations - one to be used for unstable or neutral atmospheric stability and one for stable conditions. Quantitative values of the lapse rate are required in the equation for stable conditions and not required for the equation for unstable conditions. Temperature lapse rates aloft are measured two times a day every other day on Tract C-b. The frequency of measurement is not sufficient to provide a continuous record of stability conditions at effective stack height for high emissions releases. Therefore, the acoustic radar record will be used to fill in the missing information. This approach has been suggested by Paul MacCready (1977). It is not possible to derive quantitative values of the lapse rate aloft from acoustic radar records alone, but it is relatively easy to determine atmospheric stability. The techniques for such determination are presented in Tombach, et al (1973), and the AeroVironment booklets, Acoustic Radar - Applications and Interpretation of Records, and Monostatic Acoustic Radar.

Being able to determine whether the atmosphere is stable or not at stack height will permit one to decide which of the two equations proposed by Briggs should be used in the plume rise calculations. Briggs suggested using a $\partial\theta/\partial z$ of 0.02°K m^{-1} for stability E and a $\partial\theta/\partial z$ of 0.035°K m^{-1} for stability F in the event that quantitative $\partial\theta/\partial z$ values are missing. An average value of 0.0275°K m^{-1} has been utilized in the AV model for simplicity whenever a stable condition is detected; this average value causes, at worst, a 10% deviation in the final plume rise. For initial screening, the Valley Model utilizes the actual stability case, however.

In order to verify that acoustic radar data can in fact be used in stability classifications on Tract C-b, a comparison between stability classes derived from temperature soundings and stability classes derived from simultaneously recorded radar data will be made. Comparisons between stability classes from acoustic radar and stability classes from short-term or periodic upper air temperature soundings using aircraft or tethersonde prior to September 1977 will also be performed.

In addition to obtaining stability information at effective stack height from acoustic radar records, for high level releases, mixing height and inversion height information will be obtained from those records. If a transition from a stable layer to a neutral or unstable layer occurs within 50 m of stack top, the transition will also be reorted. This information will allow the modeling of plume penetration of an inversion into a well-mixed layer. The transition from a neutral or unstable layer to a stable layer will also be reported for the modeling of plume bifurcation and fumigation. The ΔT from the meteorological tower will continue to be used to provide stability categories for low-level releases and for all cases associated with "preliminary screening" model runs using the Valley Model.

Tracer studies were conducted at the Tract in 1978 utilizing SF6 released from thethered balloons to validate the air diffusion model.

6.3.2.3 Experimental Design and Data Analysis

Sampling frequency for wind data is identical to that of the air-quality parameters. For air quality support Table 6.2-3, item 6.3.1, states that correlations of gaseous constituents and particulates will be made with wind speed and direction at a 10-m height where such correlation exists. Wind roses will be presented quarterly at the 30-m level on the tower and monthly direction-only wind roses will be presented at each station at the 10-m height.

Regarding model validation, it is understood that the model must be validated for the C-b site. The combination of data from the 60-m meteorological tower, the 1977-78 pibal (minisonde) study, the acoustic radar, and the meteorological network (Station 020, 023, 024, 042, 056) were all utilized as necessary, in the model validation and to define "worst-case" meteorological candidate conditions for modeling input.

Stability classes and mixing layer heights will be generated by hour for each month. Stability class frequency distributions will be presented as mean hourly values and as class percentages for each month. Wind persistence by stability class will be examined.

6.4 Development-Related Monitoring

As the development progresses and point-, area-, and fugitive emissions come into existence they are required to be monitored. Source emissions

monitoring will be designed to be consistent with Federal and State regulations and with AOSO requirements.

6.4.1 Emissions Monitoring

6.4.1.1 Objectives and Rationale

A permit to construct and operate the oil shale facility is required in the future from the Air Pollution Control Division of the State of Colorado Board of Health, prior to the start of such construction. As of December 16, 1977 an EPA Prevention of Significant Deterioration (PSD) permit has been obtained for the C-b ancillary facilities. Both of these permits require emissions monitoring.

The objective of emissions monitoring is to comply with requirements of both the (future) APCD permit to construct and operate, the (obtained) EPA - PSD permit, and potential AOSO requirements.

6.4.1.2 Methods

The specific requirements of the existing PSD permit have been depicted in Table 6.4-1, Emission Monitoring, C-b Tract. This table delineates monitoring for 15 separate items at 8 locations; the APCD and AOSO may require other items.

6.4.1.3 Experimental Design and Data Analysis

Specific performance test techniques for the sulfur removal facility, the steam boilers, and the mine vent and additional monitoring under the permit have been summarized on Table 6.4-2.

The specific data analysis requirements are called out in the appropriate Code of the Federal Register (CFR). Additional reporting requirements are specified in the PSD permit and will not be repeated here. As required, emissions monitoring for hazardous trace elements, organics, and potential carcinogens will be defined and delineated in the annual report prior to retorting.

6.4.2 Air Diffusion Model Validation

Principal model validation was accomplished via the tracer tests utilizing SF_6 as described previously.

After the initial ancillary retorts are operating it appears feasible that known amounts of SF_6 could be injected into the existing stacks. Ambient concentrations at specified installed receptors designed especially for low

TABLE 6.4-1

EMISSION MONITORING C-b TRACT

(Under EPA - PSD Permit)

	Hg As Se Arsine	SO_2	H_2S	Pt	CS_2	COS	RSH	NO_x	O_2	CO_2	CO	Flow Rate	Temp	Mois-ture	Opac-ity
Thermal Oxidizer		X		X											X
Stretford In	X	X	X		X	X	X					X	X	X	
Stretford Out	X	X	X		X	X	X					X	X	X	
Mine Vent		X		X											X
Mine Shaft Transfer				X											X
Shale Conveyor				X											X
ROM Ore Handling				X											X
Steam Boiler		X		X				X	X	X	X				X

SO_2 - Sulfur dioxide
H_2S - Hydrogen sulfide
Pt - Particulate
CS_2 - Carbon disulfide
RSH - Mercaptan
NO_x - Nitrogen oxides
O_2 - Oxygen
CO_2 - Carbon dioxide
CO - Carbon monoxide

TABLE 6.4-2

EMISSIONS MONITORING
REQUIRED TECHNIQUES SPECIFIED
BY THE EPA PSD PERMIT

Facility	Technique
Sulfur removal facility	Source performance tests via 40 CFR 60.7, 60.8 and EPA Method 11 or equivalent.
Steam boilers	Source performance tests via 40 CFR 60.7, 60.8, 60.13, 60.45 and EPA Methods 5, 6, 7
Mine Vent	Source performance tests for particulates via 40 CFR 60.8 and EPA Method 5
In-situ gas stream	a) Unspecified techniques for monitoring particle size distribution and chemical composition of particulates. b) Monitoring sulfur concentrations (incl H_2S, SO_2, CS_2, COS, RSH, etc.) and gas quantities via 40 CFR 60.7, 60.8 and EPA Methods 2 and 11 at inlet and outlet of sulfur removal facility.
Petroleum storage vessels	For those subject to 40 CFR 60 Subpart K record average monthly storage temp. and vapor pressure
Excess emissions at any facility	Detailed reporting requirements in PSD permit
Shale pile	Maximum of 80 acres in active working disposal state at any one time
All fugitive dust sources	Record monthly use of water, dust pallatives
Miscellaneous	Record monthly use of- a) rock tonnage removed from shafts b) blasting powder use and frequency c) diesel fuel e) gasoline

SF_6 concentrations could then be measured as time histories following the releases. Experimental details will be finalized in 1980. This technique appears to be superior to measuring ambient concentrations of SO_2 at existing trailer sites since SO_2 concentrations at many sites are expected to be very low or even below instrument minimum detectable limits.

As a goal, the model will be considered validated as follows: For the known point emission source and meteorological conditions that existed during the tracer test, ground level 1-hour-average concentrations as measured values at all valid receptor locations and as predicted by the model shall through regression analysis demonstrate a coefficient of correlation of at least 0.8.

6.5 Systems Dependent Monitoring

Figure 6.2-1 and Table 6.2-1 both show air-quality trailers at Stations 021 and 026 which are not normally expected to be activated. In the event that unforeseen high concentrations are measured at existing stations one or both of these stations may be activated. It is also possible that because of changed location of major stacks from ancillary to operational phases that shifts in predicted (via model) concentrations or in actual peak concentrations can occur. Mutual concurrence with the AOSO would be obtained prior to any such additional station activation or for shutdown or relocation of any operational station(s). Thus 021 and 026 are to be viewed as "contingencies" only.

7.0 NOISE

7.1 Introduction and Scope

The environmental noise program conducted during baseline was not required under the lease but was requested by the Area Oil Shale Supervisor. General background noise levels were sought on the Tract and surrounding vicinity prior to Tract development.

Measurements were made one working day per month for approximately one hour at the 14 locations shown on Figure 7.1-1 over a 14 month span starting in September 1975. A General Radio 1565 sound level meter has been used to obtain measurements at A, B, and C-weightings.

Measured noise levels (A weightings) above background at locations I and II along Piceance Creek Road were always made in the presence of passing vehicles. The traffic noise analysis contained in the baseline final report indicated an average level at a station on Piceance Creek Road near Hunter Creek to be 53 dbA which was exceeded 10 percent of the time. Peak noise level was 83 dbA from a road scraper in July 1976.

On-Tract activity diminished from December 1975 to almost zero in 1976 in terms of tract noise level. Noisiest activity at any Tract boundary (East, sta. XI) was that due to the jet test in November and December 1975 producing up to 75 dbA. For the most part the Tract has been very quiet.

On the basis of low noise levels existing during baseline as indicated in the above discussion, it is felt that continued discrete measurements are not warranted at all these locations. Sta. II and IX are located to indicate traffic noise levels associated with development. Periodic continuous measurements along Tract boundaries for compliance with State noise regulations are now advocated.

7.2 Environmental Noise

It is to be noted that occupational noise exposure is treated in the chapter on Health and Safety. Aspects of environmental noise treated here deal with traffic and Tract-generated noise levels.

7.2.1 Traffic Noise

7.2.1.1 Objectives and Rationale

The objective here is to measure potential increases in traffic noise level due to development.

Morning shift change is deemed to be the best time of day to make development-related measurements. Traffic levels along Piceance Creek Road and on the C-b access will be monitored with traffic counters.

7.2.1.2 Methods

A continuation of discrete noise measurements is made at stations II and IX (Figure 7.2-1) along Piceance Creek Road and on the access road at the Tract boundary to measure traffic noise during shift change. One set of measurements using the General Radio 1565 Sound Level Meter (SLM) will consist of:

1) A weighting, fast meter response for the SLM is used to measure peak noise level during the morning shift change.

2) Background levels (no traffic) are obtained the same day at each location with A, B, C, weightings.

Peak and background noise levels are reported for the month.

7.2.1.3 Experimental Design and Data Analysis

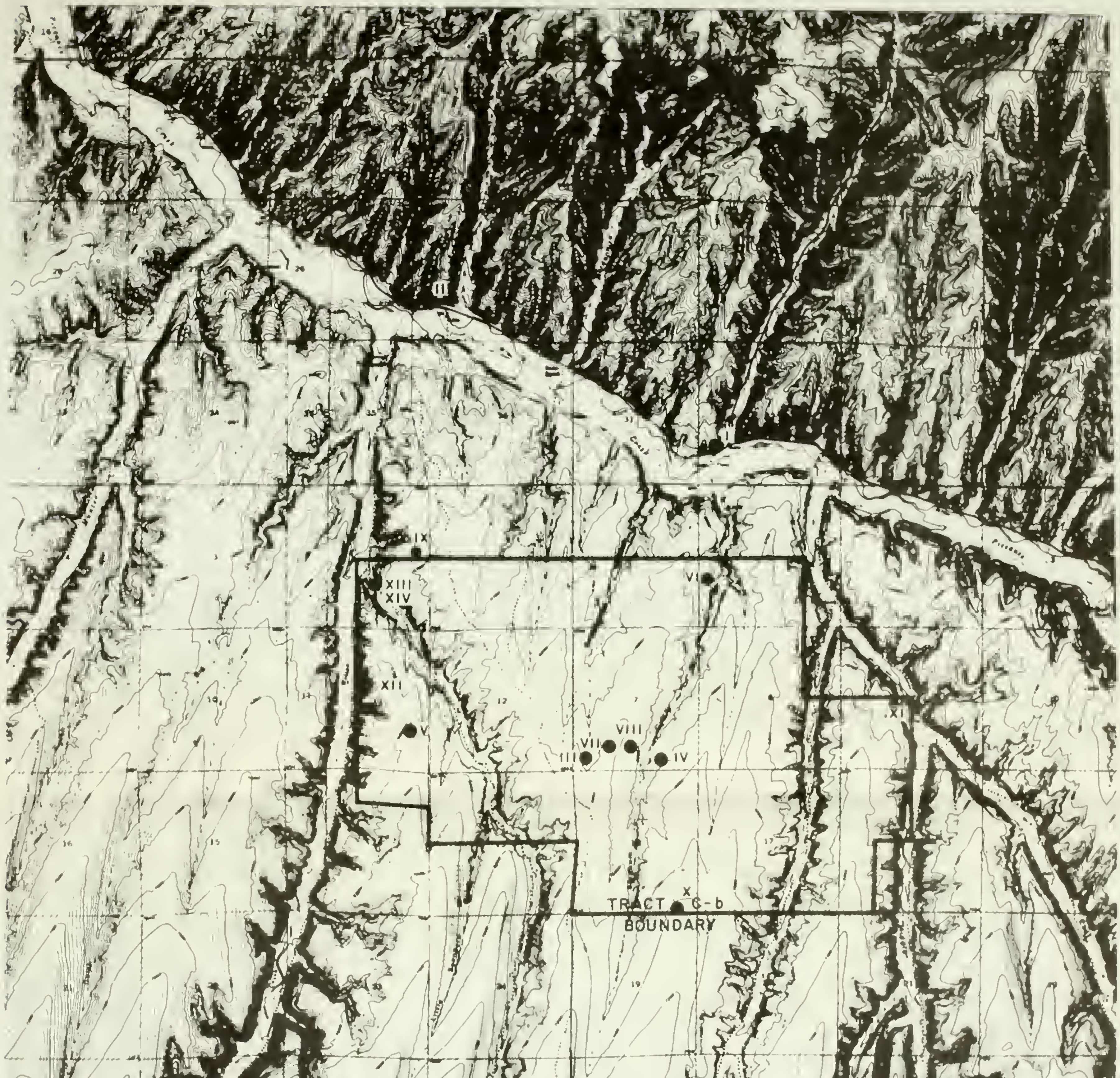
At each of the two stations peak noise levels as obtained from measurements once per week and averaged once each month and C-b traffic count will be plotted as a function of time. Trends will be noted from the graphs. See analysis Table 7.2-1.

Regarding quality assurance considerations the Sound Level Meter meets the ANSI S.1 4-1971 specifications.

The 1565 SLM is calibrated prior to taking each set of measurements with the companion 1562-A Sound Level Calibrator according to standard calibration procedure at calibration frequencies of 125, 500, 1000, and 2800 Hz. The instrument is corrected for the altitude of the Support Facility Building at the C-b Tract by manufacturer-recommended techniques by adjusting the instrument to read 112.8dB at 500 Hz instead of 114 dB indicated in the instruction manual. Design readings at all frequencies corrected for Tract altitude are:

Freq. (Hz)	125	250	500
Design Reading	114.25±1	113.6±1	112.8±1
Freq. (Hz)	1000	2000	
Design Reading	112.3±1	112.0±2	

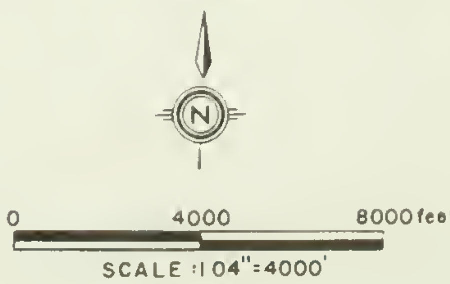
In conjuncton with using the sound level meter a windscreen is used for all the outdoor measurements and no discrete measurements are made with the wind speeds greater than 30 mph. The microphone is pointed vertically.



TRACT Cb Environmental Noise Network
During Baseline

IX
● = Noise Level Station Location

Figure 7.1-1



● Traffic Noise Station - Shift Change - 1 day/week

■ Tract Noise Surveillance - Continuous-every 6th day

NOISE ENVIRONMENTAL MONITORING NETWORK
Figure 7.2-1

7.2.2 Tract Noise

7.2.2.1 Objectives and Rationale

The objectives here are: 1) to measure increases in Tract noise due to Tract development at a representative location; 2) to demonstrate compliance with State noise regulations.

State noise standards for an industrial zone are as follows in terms of maximum allowable noise levels:

Steady:	80 db(A)	7am to next 7pm
	75 db(A)	7pm to next 7am
15 min in any one hour	90 db(A)	7am to next 7pm
Periodic, impulsive,	75 db(A)	7am to next 7pm
shrill	70 db(A)	7pm to next 7am

They apply within 25 feet of the property line (Tract boundary).

During the ancillary phase practically all development occurs near the northern boundary of the Tract, at least closer to that boundary than any other boundary. Thus a site (Sta. XV on Figure 7.2-1) along the northern boundary is most appropriate during the ancillary phase. Inasmuch as it is near the proposed ancillary facilities it is judged also to be representative location.

In the event that it appears that principal deer migration routes may have been substantially influenced by noise sources, such sources will be monitored as a systems-dependent monitoring category.

7.2.2.2 Methods

Continuous noise measurements are made at Station XV (Figure 7.2-1) on the northern boundary of the Tract for 24-hours every 6th day.

The sensor recording system consists of the following B&K instruments:

Model 2203	Precision Sound Level Meter with 0.5" microphone
Model 4230	Portable Acoustic Calibrator
Model UA 0393	Microphone Rain Cover
Model UA 0381	Wind Screen with Spikes
Model UA 0308	0.5" Dehumidifier
Model 2306	Portable Graphic Level Recorder

In this model the SLM is coupled to the battery-operated linear recorder for 24-hours of unattended all-weather operations at an A-weighting.

Table 7.2-1 NOISE ANALYSIS MATRIX

NUMBER	STUDY TITLE	PURPOSE	NUMBER OF STATIONS	SAMPLING FREQUENCY	REPORTING INTERVAL	SAMPLE DEFINITION	CALCULATIONS
7.2.1	TRAFFIC NOISE	To determine approximate influence of Trace development on access corridor noise levels.	Two - one sta. along Piceance Creek Rd., & one sta. on the Access Rd. at the Tract boundary	WEEKLY	MONTHLY	One random measurement-1 day each month during shift change. Peak and background noise levels will be reported.	None
7.2.2	TRACT NOISE	To demonstrate compliance with State noise standards for an industrial zone.	One station along Northern Tract boundary	Continuous for 24-Hr. every 6th day.	12-Hour time period.	Continuous monitoring reduced to peaks for each 12-Hr time period, and the high 15-min value between 7am and 7pm. Measurements are made for 24-Hours every 6th day.	Peak and background noise levels in each 12-Hour period. Monthly peak 12-Hour values by time period.

NUMBER	SAMPLE SIZE	COMPARISONS SPATIAL	COMPARISONS TEMPORAL	PARAMETER COMPARED	HYPOTHESES TESTED	STATISTICAL TECHNIQUES USED	TEST LEVEL OF SIGNIFICANCE	GRAPHIC PARAMETERS
7.2.1	Discrete measurements of 1) A weighting using SLM to measure peak noise level during the morning shift change. 2) Background levels (no traffic) obtained the same day with A, B, C weightings.	None	Monthly peaks vs time.	None.	None.	None.	NA	Peak noise levels vs time (Months)
7.2 2	Continuous measurement of noise using A weighting, (in decibels).	None.	Monthly 12-Hr peak vs time, 12-Hr peaks vs time.	Every 6th day.	No change in 12-Hour peak vs time	Time series analysis.	95% confidence.	Histograms of monthly peak values vs time, plots of 12-Hour peaks.

ABBREVIATIONS:

NA Not Applicable
SLM Sound Level Meter

7.2.2.3 Experimental Design and Data Analysis

The hypothesis tested (Table 7.2-1) via time series analysis at 95% confidence is that there is no change in each (7am - 7pm, 7pm - 7am) 12-hour peak over time. These peaks are obtained from continuous observations every 6th day during the month. In addition 12-hour average sound levels and background levels are reported monthly as histograms. For comparison with standards, for any peaks in excess of 80 db (daytime), duration of such excesses in minutes will be estimated and reported along with peaks.

Near the peak of the deer-migration season, deer numbers at selected stations along Piceance Creek near the Tract will attempt to be correlated with 12-hour noise peaks in that time period.

Regarding quality assurance the SLM is calibrated before each day's use with its portable acoustic calibrator to ± 0.25 db accuracy at 93.6 db, 1 kHz. The linear recorder for a 50 db range is calibrated before and after each day's use. Thus any drifts are readily apparent. Time references are annotated before and after operation.

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8.0 BIOLOGY

8.1 Introduction and Scope

The principal aim of the biological monitoring program is the continued evaluation of biotic conditions and then interaction with abiotic conditions in the Tract C-b ecological systems. This effort is concerned with the identification of trends and/or changes in system variables and processes, the identification of causes for change, and the mitigation of such effects where appropriate. Individual studies will focus on the collection of data on biotic variables and processes selected through the application of the criteria explained in the Introduction.

The selection process will be an evolving one via the feedback mechanisms that exist between the studies initiated and the data obtained. This will allow systematic alterations to be made in the types of programs and the methodologies employed as our knowledge of the variables, processes, and various interactions in the system increases.

The selection of the key variables and processes (Table A-1) provides for a critical focus on components of the Tract system that are important to system function. Moreover, the majority of the variables chosen are those that provide information relative to early warning indication of system change. The hypotheses-testing approach effectively assures that significant changes will be detected through proper and appropriately rigorous analytical data comparisons. The biological monitoring program will be initiated in phases that correspond to the level of developmental activity. The basic design of the monitoring program is the study of control (non-affected) sites and developmental (potentially affected) sites. The use of control and developmental sites permits the monitoring of long-term trends at affected and non-affected sites, and the analysis of any corresponding differences over time developing in these sites. Secondly, by applying testing procedures to control and developmental sites in any given year, differences and their probable causes can be detected. By this approach oil-shale-development-related changes can be segregated from naturally occurring changes.

The Development Monitoring activities map (Fig. 8.1-1) depicts locations of sampling sites for each of the monitoring variables given in Table 8.1-1. Sites lost due to future tract development will be noted on Fig. 8.1-1 prior to such development.

Data collected from the biological monitoring programs will be subjected to statistical treatments shown on Table 8.1-2 unless such statistical analysis is proven to be of no utility. Statistical comparisons to be used are indicated thereon for each variable to be monitored.

A significant difference is defined for each program at a level for which the stated null hypotheses can be accurately tested. Levels of significance are broad enough to absorb natural fluctuations, as observed during baseline

studies in the specific population studied, but limiting enough to reject the null hypothesis when abnormal fluctuations are discovered. A null hypothesis rejection leads to more intensive studies. Additional statistical treatments are discussed in Chapter 12, such as time-series analysis, which in some cases will be used.

8.2 Big Game--Deer

Big game refers primarily to mule deer, since they are the only large mammal common to the C-b study area. Intensive studies of mule deer are justified since deer are: 1) a major herbivore of ecological importance, and 2) a game species of economic importance. In addition, they are vulnerable to impact from development activities, road kill, and increased hunting pressure. Study transects and sample sizes are based on adequate samples obtained during baseline.

Monitoring of mule deer attempts to show the significance of Tract C-b to their survival. This is accomplished through the following variables: 1) deer-use days, 2) distribution and migration, 3) road kills, 4) mortality, and 5) age class.

8.2.1 Deer-Days Use

8.2.1.1 Objectives and Rationale

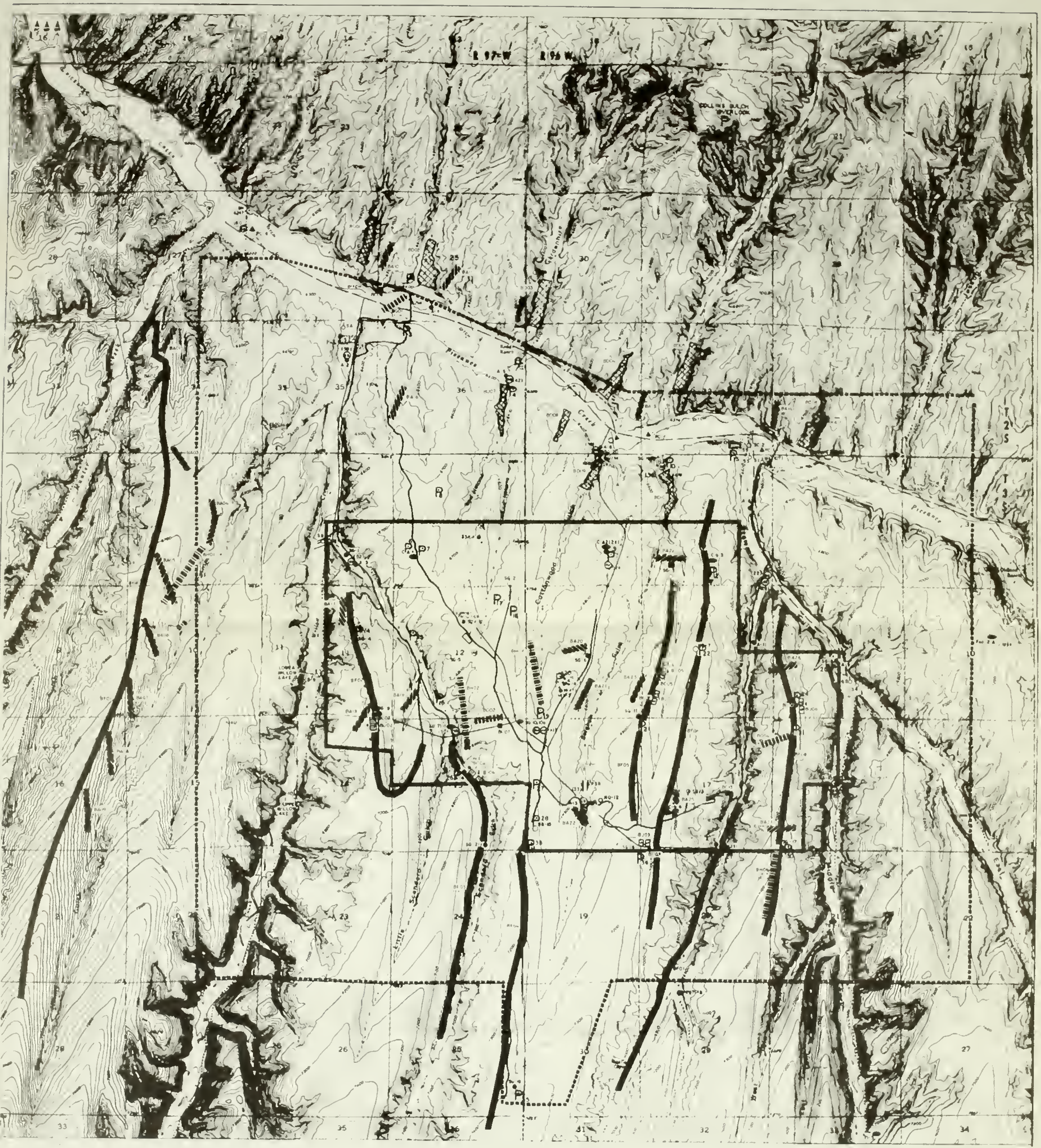
The importance of the Tract C-b to deer can be evaluated by an estimate of deer-days use, based on pellet-group counts.

8.2.1.2 Methods

Deer pellet-groups will be counted on the permanent plots. These plots will be raked free of pellets in the fall and pellet-groups counted in the spring.

8.2.1.3 Experimental Design and Data Analysis

Two habitat types are sampled, pinyon-juniper woodland and chained pinyon-juniper. Fifteen transects are located in the chained habitat type and twelve transects are located in the woodland. These same transects are used for lagomorph and browse utilization and production transects. Each transect consists of 20 plots which appear as follows on page 113.



LEGEND

(WU42) Water Gaging Station

Aquatic Sampling Site

VO VF Vegetation Site: VO: Open (50 x 70 m) VF: Fenced (50 x 70 m) (BJ)

Microenvironmental Station (BC)

Public Power Line

C-b Power Line

Study Area Boundary (BI)

Small Mammal Trap Site (BG)

Deer Pellet and Browse Utilization Transects (BA)

Ornithological Gamebird Study Transects (BH)

Predator Scent-Post Survey Lines (BF)

x Deer Distribution and Migration (BM & BN)

Deer Mortality Sites (BD)

BIOLOGICAL DEVELOPMENTAL MONITORING PROGRAM

FIGURE 8.1-1

TABLE 8.1-1

VARIABLES FOR C-b BIOLOGICAL MONITORING PROGRAM

VARIABLE	SAMPLING PERIOD AND/OR INTENSITY	APPROXIMATE STARTING DATE
Deer-Days Use	Once per year in chained pinyon-juniper rangelands and pinyon-juniper woodlands.	June 1
Distribution and Migration	Mid September through May - Highway 64 to Rio Blanco.	September 15
Road Kills	Mid-September through May - Highway 64 to Rio Blanco.	September 15
Mortality	Once each year in Spring in lateral draws and bottomland sagebrush north of Tract.	June 1
Age-Class	Twice each year in fall and spring in meadows adjacent to Piceance Creek.	November and April
Medium-Sized Mammals:		
Coyote Abundance	Once each year along 15 miles of road segments on Tract C-b and 15 mile segments west of Tract C-b.	September 15
Lagomorph Abundance	Once each year in the chained pinyon-juniper rangelands and pinyon-juniper woodlands.	June 1
Small Mammals:	Twice per year in spring and early fall in chained pinyon-juniper rangelands, pinyon-juniper woodlands and bottom-land hay meadows.	June 1 and September 15
Avifauna:		
Songbird:		
Relative Abundance and Species Composition	Three times each year in pinyon-juniper rangelands and pinyon-juniper woodlands.	May 15
Upland Gamebirds:		
Mourning Dove		
Relative Abundance	Three times each year in pinyon-juniper rangelands and pinyon-juniper woodlands.	May 15
Raptor Activity	Twice each year during the appropriate breeding season nest occupancy will be checked. Also, throughout the year all raptor sightings within the study boundary will be recorded.	March and June

TABLE 8.1-1 (Cont'd)

VARIABLE	SAMPLING PERIOD AND/OR INTENSITY	APPROXIMATE STARTING DATE
Aquatic Ecology:		
Benthos	Monthly - except winter when inaccessible.	April and September
Periphyton	Monthly through growing season.	
Water Quality	Daily with analysis only if significant difference is noted in Benthos or Periphyton.	
Terrestrial Vegetation:		
Community Structure and Composition	Three-year rotational sampling in each of the six extensive study plots established in the four major vegetation types.	June 10
Herbaceous Productivity and Utilization	Once each year in four exclosure locations and 65 range cages established in the four major vegetation types. In addition, 5 line transects for sampling the fertilization plots.	July 1 - Exclosures, August 1 Cages, transects
Shrub Productivity and Utilization	Once each year in six exclosure locations and 60 range cages established in the four major vegetation types.	July 1
Shrub Productivity and Utilization	Twice each year along 31 transects used also for deer-day use.	June and September
General Condition-Vegetation	Yearly over all the Tract.	June 10 Starting in 1979
Micro-Climatic Studies	Twice monthly at ten baseline sites.	

TABLE 8.1-2

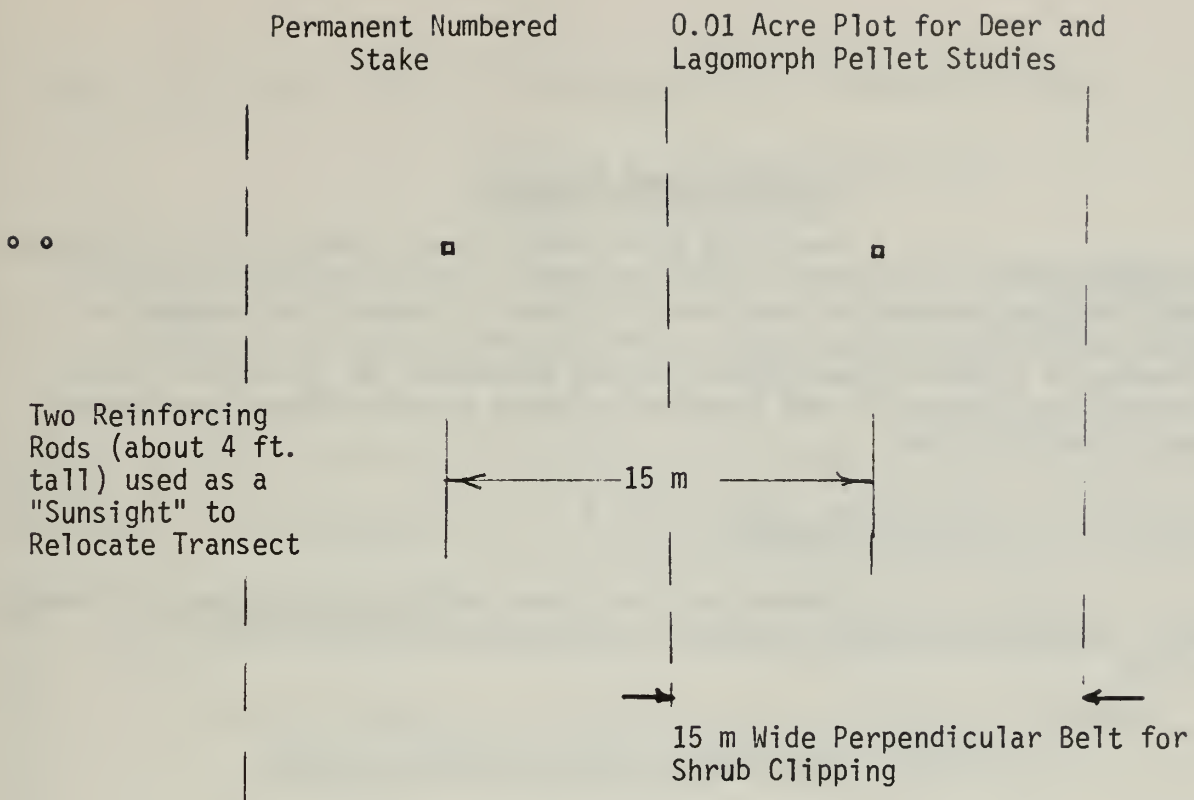
BIOLOGICAL ANALYSIS MATRIX

NUMBER	STUDY TITLE	PURPOSE	NUMBER OF STATIONS	SAMPLING FREQUENCY	REPORTING INTERVAL	SAMPLE DEFINITIONS	CALCULATIONS
8.2.1	DEER-USE DAYS	To determine deer day use per acre using development and control areas in winter season.	D 3 PJ-CH 6 PJ C 12 PJ-CH 6 PJ	ANNUAL (Dates deer move in and out must be recorded. Number of days in interval recorded.)	ANNUAL	Pellet groups per area. Number of groups in area with minimum of 15 pellets for group.	Deer-day util/acre = Pellet group/acre / Defication rate Number of deer/acre = Deer day util/acre / # of days in period Defication rate = 13 per day. Total number of deer = Deer/Acre x # of acres.
8.2.2	DEER DISTRIBUTION AND MIGRATION	To determine seasonal and year to year movement pattern of deer.	82 stations; mile-segments on each side of Piceance Creek Road for 41 miles.	WEEKLY Between mid-Sept and mid-May. Approximately 37 weeks per year.	Weekly count by station. Monthly count by stations.	1 mile segment on 1 side of road as far as can be seen. Count begins one hour ± 15 minutes before dusk.	Number observed.
8.2.3	DEER ROAD KILLS	To determine areas and numbers of highest road kill.	Same as above	Same as above.	Same as above.	For same stations as above, number of fawns, yearlings, and mature by sex killed each week.	Number observed.
8.2.4	DEER MORTALITY	To determine relative abundance of deer mortality in selected gulches	Ten plots.	Once per year in Spring.	ANNUAL	Number of dead deer by age and sex if possible.	Number observed.
8.2.5	DEER AGE CLASS	To determine fawn to adult ratio in Fall and Spring.	Tract survey in Fall and Spring.	Twice per year (Once in Spring and once in Fall).	ANNUAL	Number of fawns versus number of adults in survey.	Fawn to adult ratio. Fawn to doe ratio if possible.
8.3.1	COYOTE ABUNDANCE	To determine relative abundance of coyotes on and around tract study area.	2 transects.	ANNUAL-Stations checked the morning following preparation.	ANNUAL	Occurrence of tracks at scent stations. Three foot circle at 0.3 mile intervals along transect	Frequency of occurrence.
8.3.2	LAGAMORPHS	To determine relative abundance of rabbits.	Same as 8.2.1 .	Same as 8.2.1.	Same as 8.2.1.	Presence or absence of pellets.	Frequency of occurrence.
8.4.0	SMALL MAMMALS	To determine species composition reproductive conditions, age classes, and relative abundance.	Four study sites-2 in agricultural meadows (1C and 1D), 1 in PJ, and 1 in PJ-CH.	Twice yearly once in Spring and once in Fall, for three consecutive nights.	ANNUAL	Captures per transect.	Relative abundance and ratios.
8.5.1	SONGBIRD RELATIVE ABUNDANCE AND SPECIES COMPOSITION	To detect changes in songbird relative abundance, population density, and species composition.	4 transects- 2 Developmental 2 Control	Three times yearly from late May through June.	ANNUAL	Species list and number of each species.	Population densities and relative abundance.
8.5.2	UPLAND GAMEBIRDS MOURNING DOVE RELATIVE ABUNDANCE	To detect changes in mourning dove relative abundance.	Same as above.	Same as above.	Same as above.	The number of mourning doves in each transect.	Same as above.
8.5.3	RAPTOR ACTIVITY	To determine changes in raptor utilization of C-b.	The entire tract & surrounding study areas.	a) Annual per Species for nesting. b) Random Observations for entire year.	ANNUAL	a) Nest Occupancy -no. of nests being used. b) Random observations - species list & no. of each species.	a) Number occupied. b) Number observed.
8.6.1	BENTHOS	To infer water quality from invertebrate species present.	3 USGS Stations: 061,058,007.	MONTHLY	MONTHLY	Invertebrate species list & number of each species.	NONE
8.6.2	PERIPHYTON	a) Bioproductivity as a function of water quality b) infer water quality from species present.	Two: PC-6, PC-1.	MONTHLY from May through Oct.	MONTHLY	a) Bioproductivity (mg/cm^2). b) Species list, density, diversity, and abundance.	a) mg/cm^2 by station. b) NONE
8.6.3	WATER QUALITY (AQUATIC ECOLOGY)- Listed under Hydrology						
8.7.1	VEGETATION COMMUNITY STRUCTURE AND COMPOSITION	To measure change in community structure over time by development (D) and control (C) sites.	2 Control plots (C) 2 Developmental plots (D)	Every 3 years (2 sites per year).	Every 3 Years (2 sites per year).	a) Species list by station. b) % herbaceous species frequency and cover found. c) % shrub species in belt transect.	a) NONE b) % herbaceous species frequency and cover by station. c) % shrub frequency, density & cover.
8.7.2	HERBACEOUS PRODUCTIVITY AND UTILIZATION	a) Herbaceous production in each of four vegetation types at exclosures. b) Herbaceous production used by herbivores at exclosure areas. c) Herbaceous production and utilization for vegetation types in the Tract area.	a) 4 Exclosures, 2 Developmental (D) 2 Control b) Same as a) c) 120 randomly placed plots. (See text).	ANNUAL	ANNUAL	a) 1-m^2 quadrats per vegetation type. b) Same as (a) above c) Same as (a) above	a) Productivity in kg/hectare b) % Productivity utilized. c) Same as (a) and (b) above; utilization by wildlife is difference between productivity of open and fenced areas at a given site.
8.7.3	SHRUB PRODUCTIVITY & UTILIZATION	Evaluation of browse available to herbivores and quantities utilized.	a) Bitterbrush: same transects as 8.2.1. 10 shrubs/transect. 10 samples/shrub. b) Sagebrush; utilization; same transects as 8.2.1. 50 samples/transect. Hedging study & age class study give utilization. c) Perm. Plots; 9 transects on B J. Ridge.	ANNUAL	ANNUAL	a) lbs/acre and % utilization for productivity. b) Arbitrary measurement of use. c) Number of living bitterbrush and mountain mahogany per 0.04 acre quadrat, height of bitterbrush, number of seedlings per 0.003 acre quadrat.	a) Productivity in lb/acre. b) NONE c) % living bitterbrush and mountain mahogany/acre.
8.7.4	GENERAL CONDITION (via color and infrared (CIR)).	To evaluate the overall condition of vegetation.	Tract survey.	ANNUAL	ANNUAL	Photos of Tract area.	NONE
8.7.5	MICROCLIMATE STUDIES	To relate measured microclimatic conditions to plant and animal data.	10 Stations - 5 sta in developmental sites, and 5 sta in control sites.	Every 2 weeks	Every 2 weeks.	4 parameters at all stations: Air Temp. at 1m, Soil Temp at surface; Total prec., & snow depth & moisture content.	Monthly values max. and min. temp., soil temp., precip. totals, snow depth, and moisture content.
8.8.1	THREATENED & ENDANGERED SPECIES-PLANTS	To identify the existence of threatened species in the Tract region.	Entire Tract region.	CONTINUOUS	Only if observed.	Addition to species list at time of sighting.	NONE
8.8.2	THREATENED & ENDANGERED SPECIES WILDLIFE	Same as above.	Same as above.	CONTINUOUS	Only if observed.	Addition to species list at time of sighting.	NONE
8.9.1	REVEGETATION STRUCTURE AND COMPOSITION	To assess the progress of growth of re-established vegetation.	10 Stations-to be located on disturbed sites and on raw shale pile.	Yearly	Yearly	Determination of species frequency, % cover by species, % cover by litter, soil, rock, mosses and lichens. Herbaceous species & shrubs less than 1.25 ft in ht. will be sampled.	Percentages.
8.9.2	PRODUCTIVITY ON REVEG. SITES	To determine the vegetation biomass change on revegetated areas.	50 1-m^2 plots (5 clipped and 45 ocular estimates).	ANNUAL	ANNUAL	Measurement of vegetative productivity in lb/acre.	Productivity in kg/ha, variance

NUMBER	SAMPLE SIZE	COMPARISONS SPATIAL	COMPARISONS TEMPORAL	PARAMETER COMPARED	HYPOTHESES TESTED	STATISTICAL TECHNIQUES USED	TEST LEVEL OF SIGNIFICANCE	GRAPHIC PARAMETERS
8.2.1	27 transects with 20 plots per transect, 540 plots. (plot = .01 acre)	DPJ-CH vs CPJ-CH DPJ-AQA vs CPJ-AQA.	Dev Stations vs time. Cont. stations vs time.	Mean density	H_0: No diff. exist among the means of the pellet groups of selected transects. H_0: No diff. exist among the C & D sites on a year to year basis.	Numeric comparison, T-Test, Single factor ANOVA.	α=0.10	Mean densities by habitat type vs time for dev & control separately.
8.2.2	82 Stations. Deer count.	Stations to stations for given week and for season.	Week to week by stations. Year to year by stations.	Count	H_0: No diff. exist among the local deer concentrations on a year to year basis	TABULATION- Monthly time series for total count & selected stationgroupings, G-Test.	α=0.10	On map, count by mile and side by week, and histogram of counts by mile.
8.2.3	Same as above.	Station to station by sample category.	Same as above.	Count	H_0 No diff. in road kill over time.	TABULATIONS-G-Test, Road kill simulations.	α=0.10	Same as above.
8.2.4	Number counted in all surveys.	Plot vs plot	Year to year comparisons of plots.	Count	H_0: No diff. on a year to year basis. H_0: No diff. among plots.	TABULATIONS - G-Test.	α=0.10	Not needed.
8.2.5	Number counted in surveys.	Selected areas on and near Tract	Fall to Spring and year to year.	Ratio	H_0: Ratio does not change from year to year.	Numeric comparison of Fall to Spring. Road kill simulation model, multiple time series. T-test for proportions.	α=0.10	NA
8.3.1	Approximately 15 miles of control transect and 15 miles of developmental transect.	Control vs Developmental.	Year to year for control, developmental and GMU22	Occurrence within plots.	H_0: There is no diff. between control and developmental. H_0: No diff. from year to year.	G-Test. T-Test.	α=0.10	Percent of occurrence over time
8.3.2	Same as 8.2.1	Same as 8.2.1.	Same as 8.2.1 .	Occurrence within plots.	H_0: No diff. in abundance between C vs D transects now or over time.	G-Test.	α=0.10	Percent of occurrence over time.
8.4.0	In ag. meadows-4 transects (25 Traps/transect). In PJ & PJ-CH-2 transects. Traps checked for 3 consecutive nights for a total of 900 trap nights.	Control vs Developmental.	Year to year for developmental and control.	Relative Abundance.	H_0: Species population parameters are the same between C and D and over time.	G-Test for abundance and reproductive condition. Shannon-Weiner for species composition.	α=0.10	Time oriented plots of parameters.
8.5.1	4 Transects with 3 samples ea. for 1st period & 1 sam ea. for the 2nd & 3rd periods.	C relative abundance & species comp. vs D pop. density, rel. abund. & sp. comp.	Relative abundance and species composition vs time for each plot	Relative abundance Composition.	H_0: No diff. from year to year by plot H_0: No diff. between Dev. & Cnt. for year.	ANOVA.	α=0.20	None
8.5.2	Same as above.	Control relative abund vs Dev relative abund.	Relative abundance vs time for each plot.	Relative abundance.	H_0: No diff. in abundance over time by plot. H_0: No diff. between Dev. & Cnt for year.	Same as above.	α=0.20	None
8.5.3	Number observed for nesting and for random count.	None	Relative abundance vs time for study area for nesting and for count.	Abundance.	H_0: No change in relative abundance from year to year for nesting & for random observations.	a) Professional Judgement, possibly G-Test. b) Same as above.	α=0.10	None
8.6.1	Invertebrate species list and count for each station.	Relative abundance and diversity trends by station	Relative abundance and diversity trends over time.	Relative Abundance and Diversity.	H_0: No change in communities from baseline. H_0: No diff. bet. Dev. & Cnt. sites	Shannon-Weiner, T-Test for proportions.	α=0.10	Abundance vs time.
8.6.2	a) Three slides/station. b) Three slides/station.	a) Bioproductivity between stations. b) Species list, density, diversity and abundance	a) Time history by station. b) Species list, density, diversity, abundance.	a) Bioproductivity. b) Species list, density, diversity, abundance.	H_0: a) No difference in means over time. b) No difference in means over time.	a) T-Test. b) Shannon-Weiner, ANOVA, correlation, G-test.	α=0.10	a) Bioproductivity vs time. b) Density and abundance vs time.
8.6.3	Water Quality (Aquatic Ecology) - Listed under Hydrology							
8.7.1	a) Species list. b) 25 1-m^2 (one centare) quadrats/site for herbs. c) 20-4 x 10m transects/ plot for shrubs.	a) Species list. b) C vs D in PJ and PJ-CH for herbs. c) Same as (b) above for shrubs.	a) Species list. b) US, BS, each over time. c) Same as (b) above for PJ and PJ-CH.	a) None b) % species frequency and cover. c) % frequency, density, and cover.	a) Qualitative table. b) No diff. in means of C vs D; No diff. over time between stations for herbs. c) Same as (b) above for shrubs.	a) NA b) T-Test, paired sign test, Newman-Keuls, ANOVA, and Regression Analysis for herbs. c) Same as (b) above for shrubs.	a) NA b) α=0.20 for herbs. c) Same as (b) above for shrubs.	a) NA b) % frequency and cover over time for herbs. c) % frequency, density and cover over time for shrubs.
8.7.2	a) 50 1-m^2 plots per site for 4 sites b) Same as (a) above. c) 120 1-m^2 plots (60 caged and 60 uncaged) randomly placed in the four vegetation types.	a) C vs D in PJ and PJ-CH b) Same as (a) above. c) Production/utilization between 4 vegetation types.	a) C and D vs time. b) Same as (a) above. c) Production/Utilization vs time.	a) Annual production. b) Annual utilization. c) Same as (a) and (b) above.	a) No diff. in annual production of C vs D. No diff. in time by station. b) Same as (a) above for annual utilization. c) No diff. in annual production or utilization between vegetation types or over time.	a) Newman-Keuls F-Test, ANOVA. b) Same as (a) above. c) Same as (a) above.	a) α=0.10 b) Same as (a) above. c) Same as (a) above.	a) C and D Productivity vs time. b) Utilization vs time. c) Productivity vs time. Utilization vs time.
8.7.3	a) 10 shrubs/transect. 10 samples/shrub. b) 100 samples per transect. c) 20 quadrats/transect.	a) C vs D. b) C vs D. c) Big Jimmy Ridge vs Tract.	a) C and D vs time. b) Same as (a) above. c) Same as (a) above.	a) Same as 8.2.1. b) Same as 8.2.1. c) % of living shrubs, height, and reproduction.	a) H_0: No sign. diff. among the util. estimate of bitterbrush. Comparison will be between appropriate groups of transects. b) H_0: No sign. diff. among sagebrush conditions in D vs C transects. c) Same as (a) above.	a) T-Test, G-Test. correlation with deer. b) Same as (a) above c) Same as (a) above.	α=0.20	Utilization vs time
8.7.4	Entire Tract area.	Professional judgement of change between the baseline and following year	Variation of condition over time.	NONE	No specific hypothesis.	NONE	NONE	Maps with overlays.
8.7.5	10 samples-1 @ MC station (4 parameters/ sample).	NONE	Each parameter over time by station.	NONE	H_0: No diff. in temp. over time between sites. H_0: No diff. in prec., between sites.	Single time series, T-Test, Chi-Square, correlation with plant and wildlife data.	α=0.10	Parameter vs time
8.8.1	Entire Tract region.	NONE	NONE	NONE	NONE	NONE	NONE	NONE
8.8.2	Entire Tract region.	NONE	NONE	NONE	NONE	NONE	NONE	NONE
8.9.1	10 1-centare quadrats per site x 10 sites = 100 plots.	Species cover at site vs cover at any other site.	Species frequency vs time	NONE	H_0: No change in species freq over time at any site. H_0: No change in species cover over time at any site.	T-Test. Paired sign test, G-Test.	α=0.10	Observed frequency vs time.
8.9.2	1-m^2 plots.	To Be Determined.	Productivity over time; professional judgement to compare to drill pads in same veg type.	NONE	H_0: No significant change exists in standing crop at any one site. H_0: No significant diff. exists in standing crop over time between sites.	ANOVA over time.	α=0.10	Productivity vs time Total productivity of disturbed areas with like veg. type

ABBREVIATIONS:

Ag Agricultural
AQA Air Quality Assessment
B.J. Ridge Big Jimmy Ridge
BS Bottomland sagebrush
C Control sites
CH. Chained
CIR Color infra Red
CM^2: Centimeters squared
CPJ: Chained pinyon-juniper
D: Development sites
DPJ Development pinyon-juniper
GMU22: Game management unit number 22
Ha Hectare
H_0: Null hypothesis
Kg Kilograms
M^2: Meters Squared
MC: Microclimate
Mm Millim[illegible]
PC: Piceance Creek
PJ: Pinyon-Juniper
US: Upland sagebrush
USGS United States Geological Survey



Locations of the transects are well within the boundaries of the habitat type (avoiding habitat edges), and are positioned such that comparisons can be made of development vs. control areas, i.e., oil-shale vs. non-oil-shale effects. Some of these transects are placed to the north and west of the Tract to detect shifts in distribution due to development-related activities.

Regarding analysis of deer-days use (Table 8.1-2), the hypotheses to be tested are:

H_0: No significant differences exist among the means of the pellet groups of selected transects.

H_0: No significant difference exists among the developmental and control sites on a year-to-year basis.

Results will be tested using parametric statistical methods; t-tests and single factor analysis of variance. The null hypothesis will be tested at a level of significance, $\alpha = 0.10$.

8.2.2 Distribution and Migration

8.2.2.1 Objectives and Rationale

Deer road counts have proven useful for showing deer distributions along the Piceance Creek highway. The structured road count observations are repeatable, and provide a means of quanitying changes in relative abundance and distribution. The main objectives are to record differences on a year-to-year basis of such parameters as the size of local concentrations, changes in the location of these concentrations, and seasonal changes in habitat use.

8.2.2.2 Methods

Counts are made from a vehicle driving approximately 30 mph. Tabulations of deer observed are recorded in terms of one-mile intervals.

8.2.2.3 Experimental Design and Data Analysis

Weekly sampling is obtained each year beginning in mid-September and lasts until the end of May. The sample area is the 41 mile stretch of Piceance Creek road between Rio Blanco and Highway 64. Times of migration will be based on the occurrence and disappearance of deer in the meadows. Road-killed deer will also be recorded and tabulated for one-mile intervals (see Section 8.2.3).

The main check point for determining mile intervals is Rock School (the beginning of mile interval 12 from direction of Little Hills). This check point is used to minimize variations near Tract C-b due to accuracy differences among vehicle odometers. Counts must begin one hour ± 15 minutes before dusk. The direction of travel will be altered for consecutive counts.

Deer are searched for while driving slowly; long stops (more than one minute) to search for additional deer are avoided. Although deer may be seen in a variety of habitat types, with some moving and others feeding, the locations of deer observed will be noted only in three situations. This notation is made in the table below only when the deer are obviously feeding heavily: 1) in meadows (M), 2) on south-facing slopes (S), and 3) on hay stacks (H).

Other wild mammals observed will be recorded in the table as well, especially those larger than ground squirrels. Deer are recorded only as the number of deer observed. Age class and sex-ratio counts will be made during additional evening counts (see Section 8.2.5). In addition, throughout the year all raptor and uncommon wildlife sightings in the study area will be recorded on a wildlife observation report form from the B.L.M.

Example data entries are as follows:

Piceance Creek Deer Study
Deer Count/Mortality

Date 10/25/77

Weather Clear

Mile Marker	Location	No. of Deer	M	S	H	Comments
41	White River City	5	X			
40	Piceance Bridge	0				Bobcat
39	Lower Canyon	10		X		
38	Piceance Canyon					
37	Yellow Creek					
36	Stinking Springs					Fresh road kill
35	Old Bridge					
34	Little Hills Turnoff	5	X			

The following hypothesis will be tested in this analysis (Table 8.1-2):

H_0: No significant differences exist among the sizes and distributions of local deer concentrations at selected sites on a year-to-year basis.

The data will be analyzed using non-parametric tests, such as the log-likelihood G test (Sokal & Rohlf 1967) to compare changes in observed distributions. Monthly time series tabulations of total counts and selected station groupings will be generated.

8.2.3 Road Kills

8.2.3.1 Objectives and Rationale

This variable will aid in determining the impact of increased traffic on mule deer and other wildlife.

8.2.3.2 Methods

Counts will be made from a vehicle driving approximately 30 mph. When a deer carcass is spotted it will be tagged, so as not to be recounted. Carcasses will be aged using tooth-wear criteria. Mileage from the starting point will be noted. Other road kills (domestic and wild) will also be noted; only large animals will be tagged. Additionally, in 1979, traffic counters will be placed across Piceance Creek Road near Rio Blanco, at White River City and at the access road entrance to the Tract.

8.2.3.3 Experimental Design and Data Analysis

Counts will be made once a week (not to be done during meadow distribution or age-class surveys) and will start at the junction of Highway 64 and Piceance Creek Road and end at Rio Blanco. Counts will run from mid-September until April or May when the deer have migrated to the highlands.
Regarding analysis (Table 8.1-2), the following hypothesis will be tested:

> H_0: No significant difference exists in road kills as a result of increased traffic destined for Tract C-b.

By totaling the traffic counters on Piceance Creek Road and subtracting the counts from the C-b gate, one will be able to correlate that percentage of C-b traffic responsible for deer road kills, that direction receiving the most traffic, and those areas which are critical deer crossings. Non-parametric tests will be used such as log-likelihood G test (Sokal & Rohlf 1967) to compare different areas of the road transect. Monthly time series tabulations of total counts will be generated. The deer road-kill model of Section 12.2 will be used to study possible mitigative alternatives.

8.2.4 Mortality

8.2.4.1 Objectives and Rationale

This parameter will indicate changes in the relative magnitude of deer mortality and various causes of death. Baseline

studies have shown winter kills to be largely restricted to two habitat types, lateral draws and bottomland sagebrush.

8.2.4.2 Methods

Deer carcasses, representing winter kill of the current winter, will be counted in ten permanent plots as shown on Figure 8.1-1. Carcasses will be separated by age using tooth wear criteria. An estimate of deer killed by hunters will be obtained by hunter interview on or near the tract; coordination with the Department of Wildlife will be maintained in this regard.

8.2.4.3 Experimental Design and Data Analysis

Sampling will be done once each year in the spring in two habitat types: in lateral draws and in the sagebrush gulches.

The following hypothesis will be tested in this analysis (Table 8.1-2):

H_0: No significant difference exists in deer mortality on a year-to-year basis.

Data will be analyzed using non-parametric tests, such as a log-likelihood G (Sokal & Rohlf 1967).

8.2.5 Age Class

8.2.5.1 Objectives and Rationale

Estimating the composition of the deer herd facilitates evaluation of the magnitude of fawn mortality that has occurred during spring and summer while deer were on summer range. Estimates taken in spring permit evaluation of fawn mortality that occurred while deer were on winter range in the C-b area.

8.2.5.2 Methods

Deer are observed and recorded as numbers of fawn to adults. Sex-ratio elements are also to be obtained.

8.2.5.3 Experimental Design and Data Analysis

Sampling occurs in fall and in spring. Sampling locations (Figure 8.1-1) are situated in meadows immediately north of the

Tract and major drainages within the study area. Counts are restricted to within five miles either side of Tract C-b and are conducted once during fall (October or November) and once during spring (April or May). The observations take place during times of heaviest concentrations. Animals are recorded as adults, fawns, or bucks. No attempt is made to recognize yearlings, and bucks are counted only when antlers are visible (otherwise, they are recorded as adults). The number of points on an antlered buck are only to be noted when they can be easily and quickly counted.

The following hypothesis will be tested in this analysis (Table 8.1-2):

> H_0: No significant difference exists in fawn-to-adult ratio on a year-to-year basis.

The data will be analyzed using non-parametric statistics (log-likelihood G test). Since there are no controls being used for comparing age class composition and deer mortality studies, no significance level will be set for rejecting the null hypotheses. When sufficient data become available for year-to-year proportions to be established the T-test for proportions will be used to test the null hypothesis at the 0.10 level of significance. Data from this program, combined with data from the other Tract deer studies, tagged deer from the Division of Wildlife, and the road-kill simulation model will be used to further understand the dynamics of the deer herd on and surrounding Tract C-b. Interrelationships with other ecosystem elements may be evaluated through use of multiple time series techniques.

8.3 Medium-Sized Mammals

The medium-sized mammals to be considered here are restricted to several species which are important within the Tract C-b ecosystem, coyotes and lagomorphs (cottontails and jackrabbits). Monitoring these animal groups will show important trends which will contribute to the understanding of predator- and prey-species in the Tract C-b ecosystem.

8.3.1 Coyote abundance

8.3.1.1 Objectives and Rationale

Coyotes are a major predator on Tract and therefore of ecological significance. They are of political and economic interest to the public with both strongly negative and positive supporters. Conducting scent post surveys will give the relative abundance of coyotes on or near the Tract.

8.3.1.2 Methods

Relative abundance will be estimated based on the scent post survey (Linhart and Knowlton 1975) an accepted method currently being used by the U.S. Fish and Wildlife Service.

8.3.1.3 Experimental Design and Data Analysis

Sampling will be done each year in September along 15 miles of road segments to the west of Tract C-b and 15 mile segments on or near the Tract (See Figure 8.1-1). Scent stations along the transects are checked for the presence of tracks. Track surveys also yield information on other species of mammals which may inhabit or occasionally pass through the Tract. A relative index of abundance is calculated as a visit frequency. The stations are checked the morning following the setting of the traps.

The following hypotheses will be tested in this analysis (Table 8.1-2):

H_0: No significant difference exists in relative abundance of coyotes between control and developmental areas.

H_0: No significant difference exists in relative abundance of coyotes from year-to-year.

Hypotheses will be tested using non-parametric methods until sufficient data become available. No significance level will be assigned for rejection of the null hypotheses, since there are no controls for comparisons. Professional judgment shall also be used to determine significant differences over time. Collection of this data is important to understanding the C-b ecosystem, particularly predator/prey relationships.

C-b data will also be compared to other data elsewhere in Colorado. These comparisons will greatly aid in determining the normality of the coyote populations on and near the Tract.

8.3.2 Lagomorphs

8.3.2.1 Objectives and Rationale

Cottontails and jackrabbits provide an important prey base for raptorial birds and coyotes. The cottontail is classified as a game species, but presently it is of little economic value in the vicinity of Tract C-b; however, at some future date its status could change. The lagomorph population estimates will be based on relative abundance data collected from strip transects.

8.3.2.2 Methods

Pellets will be cleaned from plots in the fall and recorded as present or absent from plots in spring. Data are in pellet/area format as a function of time.

8.3.2.3 Experimental Design and Data Analysis

Sampling would occur concurrently and along the same 27 transects that are used for deer pellet counts. Number of plots sampled will be 20 plots/transect. A relative index of abundance is calculated as a visit frequency.

The following hypothesis will be tested in this analysis (Table 8.1-2):

H_0: No significant difference exists in lagomorph abundance between developmental vs. control transects now or over time.

Non-parametric tests will be used, such as the log-likelihood G test with rejection at the $\alpha = 0.10$ level of significance.

8.4 Small Mammals

Small mammals are both a prey base for predators and a major primary consumer. Monitoring changes in selected small mammal parameters will therefore aid in assessing the effects of pollutants which may become concentrated in primary producers and should also reflect the effects of man-induced disturbances or pollutants before populations of larger animals are greatly affected. Parameters to be monitored are species composition, reproductive condition, age class and relative abundance.

8.4.1 Small Mammal Sample Categories

8.4.1.1 Objectives and Rationale

Changes in small mammal populations and species composition may reflect gross environmental perturbations while changes in reproductive condition may indicate environmental perturbations or pollutants present in lower concentrations.

8.4.1.2 Methods

Small mammal population estimates will be obtained by live trapping and mark and release methods on line transects.

8.4.1.3 Experimental Design and Data Analysis

Two samplings (spring and fall) of small mammals will occur. The spring samples will furnish a baseline to determine reproductive success for each year. The fall sample, when compared with the spring sample, will indicate reproductive success and more importantly indicate the prey base for wintering and early spring raptors.

Monitoring small mammal numbers, reproductive condition, and species composition will be carried out in control areas not expected to be affected by oil shale development, and in developmental areas which are expected to be influenced by retort emissions and Tract activities. Sites are chosen to represent chained pinyon-juniper, pinyon-juniper, and bottomland hay meadows, which are three major habitats in the Tract C-b study area and support significant small mammal populations. Sampling efforts in meadows may be more intensive than upland sites, since the meadow is where small mammal populations are more important to raptors.

There will be four study sites; two in agricultural meadows, one in pinyon-juniper (see Figure 8.1-1). The two study sites in the meadows will have four transects apiece while the remaining sites will have two transects apiece. Each transect consists of 25 live traps at approximately 15 meter intervals. Traps will be checked for three consecutive nights for a total of 900 trap nights.

The following hypothesis will be tested in this analysis (Table 8.1-2):

H_0: No significant difference exists in population numbers, reproductive condition and species composition between developmental and control sites now or over time.

Statistical tests will be utilized to compare control plot data against development plot parameters expected to be affected by shale oil development. These tests include:

Population numbers	- Chi square at $\alpha = .10$
Species Composition	- Shannon-Weiner Species
Reproductive Condition	- Chi Square at $\alpha = .10$

8.5 Avifauna

A wide variety of species of birds exist on Tract C-b and the surrounding area. The avifauna will be monitored to detect changes in avifauna species composition and relative abundance at the population level.

8.5.1 Songbird Relative Abundance and Species Composition

8.5.1.1 Objectives and Rationale

Two levels of monitoring activity detect changes in avifauna. The first level of study is focused on communities or populations of birds. It is anticipated that habitat disturbance and increased human activity associated with development of Tract C-b may affect population densities and relative abundance of the more prominent species and that these effects can be tracked over time. Also, certain species may be more affected by man-made impacts than others. These effects may be indicated by a change in species composition or relative abundance of major species within a community.

8.5.1.2 Methods

Species and population size will be determined by the Emlen strip transect method, adjusting observed numbers by the procedures being employed in the inventory/baseline program. Censuses will be conducted during periods of peak daily activities, generally within 3.5 hours of sunrise and sunset. Specified procedures used in this technique have appeared in past reports. The census will be conducted three times during segments of the breeding season: early season, mid-season and late season. The sampling frequency for each transect will be three periods at the beginning of the breeding season and one period for each transect during the middle and end of the breeding season.

8.5.1.3 Experimental Design and Data Analysis

Areas to be monitored include control transect areas which will not be affected by oil shale development and developmental transects which are expected to be influenced by retort emissions and/or tract construction. There will be two developmental transects immediately contiguous with construction activities, and two control transects in non-affected areas. Control plots will provide information on the variation of bird populations that occurs regardless of disturbances related to oil shale activities. Such information can be used to aid in determining if variations in bird populations at the developmental plots are a result of oil shale development activities or are merely a response that could be attributed to other causes, either natural or man-made.

Data collected during the inventory/baseline phase of the C-b shale oil project constitute a strong justification for limiting the bulk of avian monitoring to the breeding season. Section V E 2b (Efficiency of General Data) of the Annual Summary and Trends Report indicates reasons why monitoring in the Piceance Basin during the winter and migration periods would require extraordinary efforts and still would generally lead to data of questionable utility. Thus, for a majority of birds, monitoring will be confined to late

May through June each year at each of the control and developmental plots. To provide necessary census replication for statistical analysis, censuses will be conducted in triplicate at each of the plots for the first census period and one day each for the other census periods.

The following hypotheses will be tested in this analysis (Table 8.1-2):

H_0: No significant difference exists between relative abundance, population density, and species composition over time at a given plot.

H_0: No significant difference exists between relative abundance, species composition, and population density at control plots, vs. developmental plots during year x of monitoring.

After three years of monitoring, statistical analysis of variance will be applied to replicated census data from each of the plots to estimate variation within, as well as between sampling plots, and to determine if census replication can be decreased. Each null hypothesis will be tested utilizing the error variance and level of significance of $\alpha=0.20$.

8.5.2 Upland Gamebirds-Mourning Dove Relative Abundance

8.5.2.1 Objectives and Rationale

Field observations during the baseline data accumulation program indicated that sage grouse and blue grouse populations are so sparse on and near the Tract that no reasonable monitoring program for them can be designed to determine changes over time; thus, a monitoring program is not warranted. The mourning dove is the only upland gamebird presented in sufficient numbers to be monitored. Due to the political and economic importance of upland gamebirds, the monitoring program related to the mourning dove is discussed separately here.

8.5.2.2 Methods

Methods are identical to those for the songbirds. Throughout the year gamebirds observed will be recorded on Wildlife Observation Reports.

8.5.2.3 Experimental Design and Data Analysis

This is identical to the presentation of the Experimental Design section for the songbird-like population parameter.

The following hypotheses will be tested in this analysis (Table 8.1-2):

H_0: No significant difference exists in mourning dove relative abundance over time.

H_0: No significant difference exists in mourning dove relative abundance at control plots and mourning dove relative abundance at development plots during year x of monitoring.

The data will be analyzed in the identical manner as was described for analyzing the relative abundance for the songbird-like population parameter.

8.5.3 Raptor Activity

8.5.3.1 Objectives and Rationale

Raptor activity on Tract is monitored on a continuing basis because of the importance of raptors in the food chain, their apparent vulnerability to man's activities, their political value as threatened or endangered species, and their aesthetic appeal.

8.5.3.2 Methods

All nests located during baseline studies on Tract C-b and new nests located on Tract C-b and the control areas subsequent to initiation of monitoring will be checked annually for occupancy. In addition, sample pellets from roost sites will be collected to obtain qualitative food habit data. Throughout the year, any raptor sightings by the field biologists within the study boundary will be recorded.

8.5.3.3 Experimental Design and Data Analysis

Trends in utilization of Tract C-b and immediately contiguous habitats by raptors will be established each breeding season by determining the percent of known nest sites which are occupied by nesting pairs and comparing these data with data obtained during the baseline period and following years. Nest occupancy checks will be made annually during mid-March (great horned owls and ravens), late-April (red-tailed hawks, eagles), and early-June (accipiters, American kestrels, harriers). During the early-March and early-June checks, the relative abundance of winter and summer resident raptors hunting over the Tract and in the study area surrounding the Tract will be monitored.

Data analyses of nest occupancy will be by professional judgment and possibly a non-parametric proportion test will be used to analyze nest occupancy data and pellet analysis.

8.6 Aquatic Ecology

The variables of the aquatic program to be sampled through the environmental monitoring program are benthos, periphyton, and water quality. Because aquatic ecosystems could be secondarily affected by mining and development on Tract, aquatic monitoring is essential. Benthos and periphyton are "indicators" of a significant change in stream characteristics downstream from oil shale development. The specific changes should be apparent in water quality parameters. In addition to the quarterly water analysis, daily water samples will be collected and stored for a month after periphyton are sampled and analyzed. (Water quality sampling will be coordinated with that for hydrology). If significant differences are noted in the primary indicators (periphyton and benthos) these daily samples can be analyzed to determine if changes in aquatic biota are due to a change in water quality. Also, if a significant difference is noted a systems dependent study (fish shocking) may be initiated. The daily water sampling will reflect rapid changes in water quality that may be short lived but still have an effect on the aquatic biota. Statistical comparisons to baseline data would show alterations of baseline conditions and indicate, through correlation coefficients, the severity of the impact so that timely corrections of detrimental conditions could be made.

8.6.1 Benthos

8.6.1.1 Objectives and Rationale

The benthic species are important as lower-level consumers in the stream community as well as providing food for carnivorous species. They can be significant indicators of changes in the aquatic habitat. There are a number of organisms indicative of good or poor water quality conditions and qualitative data will give indication of changes in water quality.

8.6.1.2 Methods

The method used during the baseline and interim studies will be continued during the monitoring program. The surber sampler will be used to make benthic collections at control and development stations on Piceance and Willow Creeks by the U.S.G.S. The following aquatic sampling stations established during the baseline period will be used: GS007 (control) and GS061 and GS058 (development stations). Information from U.S.G.S. data will be used for correlations with data collected during environmental monitoring. Sampling will occur monthly and will be coordinated with surface water sampling. During winter months benthos studies may be discontinued due to inaccessibility dependent on weather conditions as determined by the U.S.G.S.

8.6.1.3 Experimental Design and Data Analysis

For each sampling period the data will be summarized as follows: identify "ecologically important" taxa, determine percent relative abundance and diversity ($\bar{d}$) trends, contrast these with previous sampling periods to ascertain seasonal trends, and compile a cumulative diversity ($\bar{d}$) table.

Each table will contain the following information.

1) Totals by order and/or family.
2) Totals by sample and station.
3) Percent relative abundance for (1) and (2).
4) Diversity ($\bar{d}$) for (1) and (2).
5) Maximum diversity ($\bar{d}$) for (1) and (2).
6) Equitability percent (e) for (1) and (2).
7) Number of taxa by sample, order, and/or family.

The following hypotheses will be tested in this analysis (Table 8.1-2):

H_0: No significant change exists in Benthos communities over time.

H_0: No significant difference exists in Benthos communities at control stations vs. developmental stations from baseline data, recognizing the differences during baseline.

Hypotheses will be tested utilizing Shannon-Weiner diversity indices and T-test for proportions at α=.10 level.

8.6.2 Periphyton

8.6.2.1 Objective and Rationale

The periphyton communities are the major primary producers in the streams. They provide a major food source for benthic organisms and some fish species. They can respond very quickly to changes in water quality, and as such can be an important parameter for early detection of habitat degradation. Periphyton are stationary; therefore, they respond to changes in water quality at given locations. Locations are: Hunter Creek Gauging Station GS061, (PC-6), and Stewart Gulch Gauging Station GS007, (PC-3).

8.6.2.2 Methods

Collection of periphyton samples is monthly from two sites, using artificial substrates (glass slides) which have been incubated in the water for at least 21 days. Sampling runs from May 1, 1978 to

November 1, 1978, resulting in six collections. Six glass slides shall be incubated at each of the two locations. At the time of collection, three slides shall be collected at each location and placed in individual plastic containers for biomass analysis (total of 6 slides). Also, three additional slides will be collected in individual plastic containers and preserved with "M-3" preservative, a modified Lugol's solution, for taxonomic identification and enumeration (total of 6 slides).

The slides collected for biomass will be ovendried at 105°C to constant weight. They will then be weighed to the nearest milligram, ashed at 500°C, rewetted with distilled water to replace the water of hydration, oven-dried, and weighed again. Biomass will be reported as mg ash-free dry weight per cm^2.

Slides collected for taxonomic identification and enumeration will be scraped into an appropriate volume of water along with a sufficient amount of preservative to limit microbial growth and/or algal decomposition. The resulting solution will be mixed thoroughly, and an aliquot withdrawn for quantitative analysis using an inverted microscope at a magnification of 560X.

8.6.2.3 Experimental Design and Data Analysis

The following data will be tabulated:

1) Species identification.
2) Total taxa by sample and station.
3) Density (units/cm^2).
4) Percent relative abundance.
5) Biomass (mg/cm^2) per sample.
6) Diversity ($\bar{d}$).
7) Maximum diversity ($\log_2$ number of species).
8) Equitability percent.

Diversity measurements will indicate, by the relative abundance of certain indicator species, the relative impact of oil shale development on the periphyton communities.

The following hypotheses will be tested in this analysis (Table 8.1-2):

H_0: No significant change exists in periphyton communities over time.

H_0: No significant difference exists in periphyton communities at control stations vs. development stations from baseline data, recognizing the differences during baseline.

Statistical analyses will be a comparison of productivity (biomass) and species diversity during monitoring versus baseline conditions, and include analysis of variance, correlation analysis, as well as non-parametric tests. A significant difference is based on statistical analysis and professional

judgment. If the null hypotheses are rejected at $\alpha=.10$ level, daily water samples will be analyzed, periphyton sampling may be intensived in an effort to pinpoint the degradation, and as previously noted a systems dependent (fish shocking) study may be initiated.

8.6.3 Water Quality

8.6.3.1 Objectives and Rationale

Correlations will be made between water quality parameters and observed changes in aquatic organisms. The water quality of surface water will be studied as outlined in Section 5.2 of the Hydrology chapter. The surface water analytical parameter list is presented on Table 5.2-1. In addition to the analytical list, measurement of stream temperature, specific conductance, pH, dissolved oxygen and turbidity will be measured in the field as outlined in Section 5.2.

8.6.3.2 Methods

During development and construction, the monitoring stations will be sampled according to the schedule and parameters listed in Table 5.2-1.

8.6.3.3 Experimental Design and Data Analysis

Data will be analyzed as noted in Section 5.2, Hydrology. In addition to monthly and quarterly water quality sampling, a daily water sample will be collected at the gauging station on Piceance Creek near Hunter Gulch, GS061. If there is an unexplainable change in benthos or periphyton the daily water samples will be analyzed (Table 5.2-1 A, B, and C).

The following hypothesis will be tested:

H_0: No significant change in water quality with time at any given site exists when compared to baseline quality.

A significant difference is defined as ± 20% of baseline water quality value. Statistical analysis for water quality is detailed in Section 5.2.

8.7 Terrestrial Studies

The terrestrial studies portion of the Environmental Baseline Program was designed to describe the predevelopment, biological environment within the study area (the dotted lines of Figure 8.1-1), and to provide baseline data to

be used in monitoring changes in the biota as a result of oil shale development. Baseline parameters were selected for their usefulness in describing the existing environment on Tract C-b. Development monitoring parameters were judged to be useful because of their measurability or observability or relative low natural variability, and/or sensitivity to expected environmental perturbations. Figure 8.1-1 is a map showing sample locations during Development Monitoring.

8.7.1 Vegetation Community Structure and Composition

8.7.1.1 Objectives and Rationale

These studies are designed to detect changes in the structural and compositional characteristics of the major plant communities. It will be important to determine whether certain species increase or decrease in abundance, and whether new species appear or are lost from the existing system. Periodic examination of changes in shrub, grass and forb density would also enable evaluation of influences relating to shale oil development.

8.7.1.2 Methods

Two control and two development plots (Figure 8.1-1) will be sampled utilizing the existing intensive study plots in the two major habitat types on the Tract i.e., chained pinyon-juniper (CPJ) rangeland, pinyon-juniper (PJ) woodland. These study plots will allow comparisons of possible developmental effects between control and developmental plots, plus baseline comparisons. One upland sagebrush and one bottomland sagebrush control site will also be monitored and compared to baseline data.

Sampling at these study sites will be carried out on a three-year rotational basis; each plot will be sampled every three years, two plots each year (CPJ in 1978, PJ in 1979 and sagebrush in 1980).

8.7.1.3 Experimental Design and Data Analysis

Parameters are monitored by repeated sampling of permanently located herb quadrats and line transects, and by repeated measurement of marked trees at permanently located study sites. Sampling employs the same methods used during baseline investigations. Shrub frequency, density, and cover are measured using 20 4x10 m belt transects (Lindsey, 1955), per plot. Herb frequency and cover will be measured using 25 1-m^2 (one centare) quadrats per site; cover by litter, soil, rock, lichens, mosses, and woody seedlings will also be measured in these quadrats. Sampling of trees in the woodland sites will include canopy cover by vertical projection (dizzy stick method).

The following hypothesis will be tested in this analysis (Table 8.1-2):

H_0: No significant changes exist in herb frequency, total herb cover, shrub frequency, shrub density, or tree canopy cover

a) between control and developmental plots and
b) over time.

Data will be analyzed using T-test, paired sign test, analysis of variance, correlation and regression analyses. Trend analysis will also be used as a test over time. Hypotheses will be tested at the 0.20 level of significance since indicated trends are of interest.

8.7.2 Herbaceous Productivity and Utilization

8.7.2.1 Objectives and Rationale

Since the herbaceous production forms the food base at least in part for the primary consumers of the site, it is important to monitor yearly production and utilization levels and also to evaluate whether the effects of development will alter the productivity or utilization of the herbaceous layer.

8.7.2.2 Methods

Control and developmental plots (Fig. 8.1-1) will be sampled utilizing the existing four intensive study plots in the two major habitat types on the Tract (i.e., chained pinyon-juniper rangeland, pinyon-juniper woodland). These study plots will allow comparisons of possible developmental effects between control and developmental plots, plus baseline comparisons.

Sampling in the four permanent study sites for productivity will be accomplished annually, utilizing a double sampling approach (Wilm 1944). Utilization will be determined by subtracting the productivity of non-fenced sites from fenced sites.

8.7.2.3 Experimental Design and Data Analysis

During the developmental monitoring period, two control and two development sites (pinyon-juniper and chained pinyon-juniper) are used to evaluate herbaceous production. The bottomland and upland sagebrush sites are control sites; no developmental sites exist due to the lack of development in these vegetation types. Therefore, herb productivity will not be sampled at these intensive study sites. At each site an area 50

meters on a side is fenced with three-strand barbed wire prior to the onset of growth in the Spring. Clipping will be accomplished once during the growing season at time of estimated peak standing crop. At this date the current live fraction in ten 1 m^2 plots will be clipped according to major vegetation fractions. Additionally, ocular estimates of standing crop will be made in the clipped plots as well as in 40 additional 1 m^2 quadrats. The clipped weights will be compared to estimated weights from the same plots and a correction factor will be derived from the additional 40 1 m^2 quadrats. A total of 40 1 m^2 quadrats will be clipped and estimated (10 clips/site x 4 sites) and 160 1 m^2 quadrats will be only estimated at the four intensive study sites (control and developmental sites in pinyon-juniper and chained-pinyon juniper). Productivity and utilization from the fenced or exclosure areas can be compared to the first three years of monitoring data that were obtained from these same areas. Cattle fences will be removed at the end of the growing season and will be re-established in a slightly different location (but still in the same vegetation types and general area) the following Spring.

In order to evaluate the variation of production throughout the Tract and obtain data for the bottomland and upland sagebrush communities, a second approach is used. A total of 40 range cages are randomly located in the major vegetation types on the Tract: pinyon-juniper woodland and chained rangeland, upland sagebrush and bottomland sagebrush. At the time of estimated peak standing crop, a 1 m^2 area is clipped from the area excluded by each range cage to determine production. These clips are divided into the same major vegetation fractions used during baseline. An additional replicate of 40 samples to determine utilization are taken from unexclosed areas lying close to the sampled range cages. Another 20 range cages are placed in the south-facing pinyon-juniper woodlands located north of Piceance Creek (an area most likely to be exposed to air emissions). Ten cages are placed in areas of anticipated developmental influences and ten in control areas. Each cage is large enough to accommodate a 1 m^2 quadrat. A replicate of 20 1 m^2 quadrats in adjacent open areas is used to determine utilization. These areas have not been sampled for herbaceous production and utilization previously and these studies are conducted during the 1978 growing season. Following this baseline, the study will become system dependent and may only be used after retorting and SO_2 emissions begin.

Two different vegetation types were fertilized on Tract, using two fertilizer treatments per vegetation type. See fertilization map, Fig. 8.7-1. To test the degree of influence of the fertilizer treatments, a range cage was placed in each treatment site and one cage used as a control. (The control for the other site is the cattle exclosure at the adjacent intensive study site). These five cages are clipped to determine production, and a replicate of five 1 m^2 quadrats in adjacent open areas is clipped to determine utilization. All clips are divided into the major vegetational fractions mentioned previously.

The following hypothesis will be tested in this analysis (Table 8.1-2):

H_0: No significant difference in annual productivity and utilization exists relative to time, development activity, and vegetation types.

The hypothesis will be tested using an F-test either on paired plot evaluations or through analysis of variance. The null hypothesis will be tested at the $\alpha = 0.10$ level of significance.

8.7.3 Shrub Productivity and Utilization

8.7.3.1 Objectives and Rationale

This parameter is designed to evaluate browse available to herbivores and the percent of the available browse consumed.

8.7.3.2 Methods

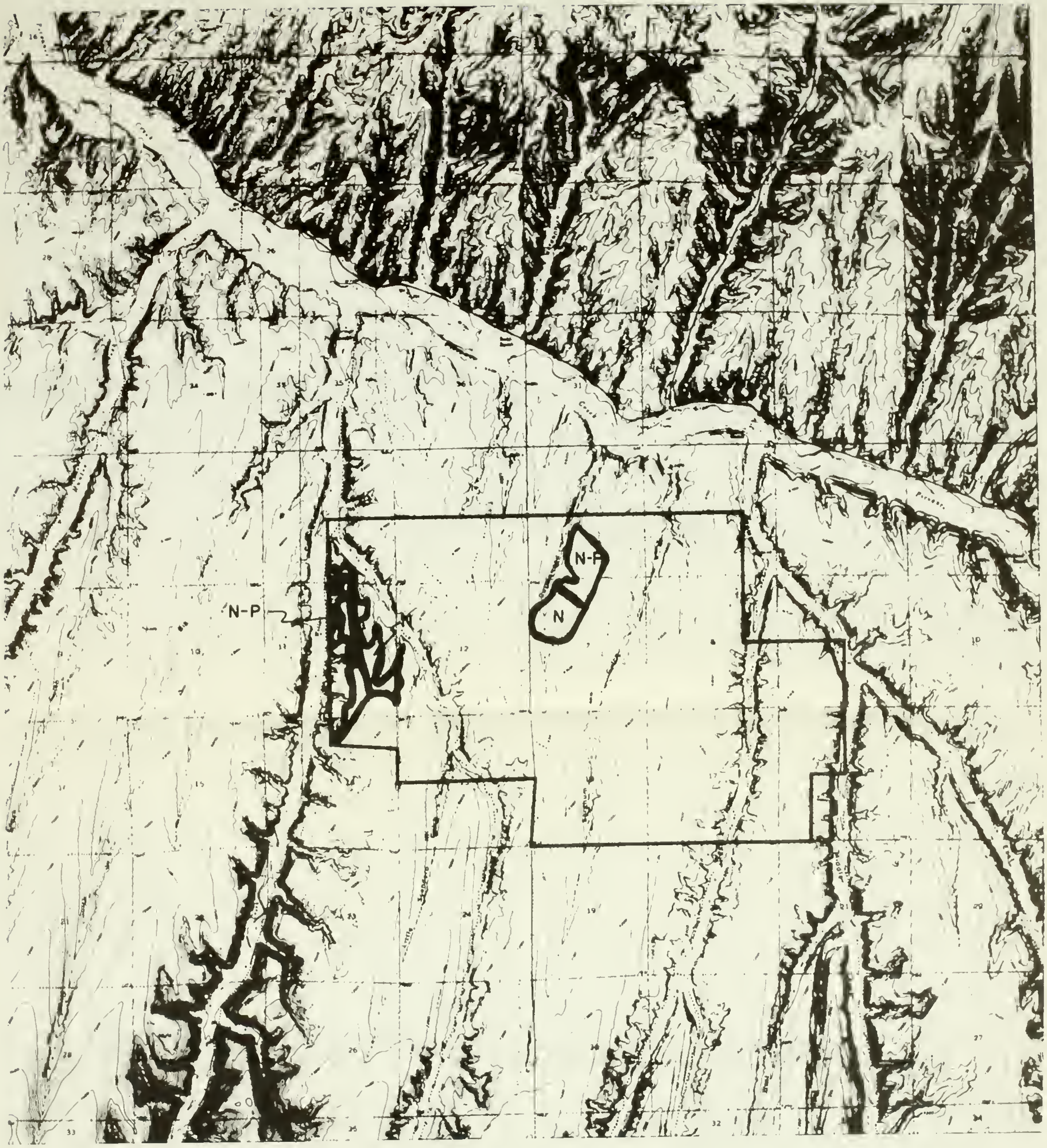
Shrub productivity and utilization of bitterbrush are obtained by taking measured samples along the same development and control transects used for deer-days use (Fig. 8.1-1). Sagebrush utilization is determined by ocular estimation along the above transects.

8.7.3.3 Experimental Design and Data Analysis

Sampling will be done in two habitat types, chained pinyon-juniper rangeland and pinyon-juniper woodland, since these represent most of the Tract C-b habitat. There will be two sample times for this annual assessment, in early spring at the beginning of the growing season to measure utilization and in the fall to assess production.

The bitterbrush stem measurement study begins in the fall to evaluate production. One shrub is selected outside the 0.01 acre plot but within the perpendicular belt by locating the nearest shrub within a randomly chosen quadrat centered on the permanent plot stake. The shrub must be greater than .15 cm tall. Ten shrubs are required for each transect; consequently, one is not compelled to locate bitterbrush at each plot. A representative stem is then chosen from a randomly chosen quarter of the shrub. A colored tag (plastic bag twister) is placed below ten shoots of current year's growth on the chosen stem. (On some shrubs it may be necessary to use more than one tag to obtain ten current shoots.) After the shoots have been tagged, they are measured and the measurements recorded. A numbered aluminum tag (which will indicate the year in which one takes the spring utilization sample) will be placed at or near the base of each shrub.

An alternate method will be used on shrubs which have been extremely browsed for which there is danger of breaking the growth while measuring. This



FERTILIZATION MAP

N-P Ammonium Nitrate & Phosphorous Fertilizer Application

N Ammonium Nitrate

FIGURE 8.7-1

method requires the choosing of two representative stems (A and B), from opposite random quarters of the shrub. On stem A, measurements are recorded for 10 shoots of current year growth. On stem B, a colored tag is placed below 10 shoots of current year's growth to be measured for utilization.

In the spring, each marked shrub and its labeled stem is located and all ten shoots are measured to determine utilization.

On the nine control transects used for deer-days use on the Big Jimmy Ridge west of the Tract a less detailed method of production and utilization is used, due to the severe browsing of the shrubs. This method involves using a 0.04 acre quadrat centered at each of the 20 stakes per transect. For each quadrat, the following are recorded: live bitterbrush and mountain mahogany; percentage (100, 75, 50, 25, or less than 25) of individual living bitterbrush, and height. Reproductive success (number of seedlings) of bitterbrush is measured within a 0.003 acre quadrat. Accomplished annually, this sampling yields trend data on shrub production, utilization, and the effects of heavy browsing. This alternative method will only be used in areas where the shrubs have been so heavily browsed that measurement with previous method is not practical. Dead twigs, witch-broomed twigs or failure to identify the terminal-bud-scale scars are indicators that this method will be required.

The sagebrush ocular estimates are conducted in the Spring along the above transects. The sampling interval is two- three-, or five-paced depending on browse density along the transect.

At each sample point the tally is recorded by age class and hedging class of the shrub whose outer perimeter is nearest the boot toe. There will be 50 samples per transect. The following description will aid in classification:

Y -- Established seedlings and young plants. Elongate growth form, simple branching; usually less than six years old, and basal stem diameter not over 1/4".

M -- Mature plants. Distinguished by heavier, often gnarled stems, complex branching, round growth form. Crown made up of more than three-fourths living wood.

D-- Decadent plants. Crowns made up of more than one-fourth dead wood.

Degrees of Hedging

L -- Little or no hedging, indicating light use in the past three or four years. Growth tends to be linear.

M -- Moderately hedged. Moderate use in past three or four years causing development of lateral branching and more complex growth form.

H -- Heavily or closely hedged. Heavy use in past three or four years causing a very much "broomed" or "clubbed" appearance.

The hypothesis to be tested in this analysis (Table 8.1-2) are:

H_0: No significant difference exists among the utilization estimates of bitterbrush. Comparisons will be between appropriate groups of transects.

H_0: No significant difference exists in sagebrush condition between developmental vs. control transects now or over time.

Results of shoot length measurements will be amenable to parametric statistical treatment (e.g., T-test, G-test, and correlation with deer data); results of ocular estimates will necessitate non-parametric procedures. The level of resolution for rejection of the null hypothesis will be at $\alpha = 0.20$.

8.7.4 General Vegetation Condition Studies

8.7.4.1 Objectives and Rationale

Since most of the other monitoring programs are site specific or aimed at individual species, it is beneficial to implement a program which allows for a complete overview of the Tract vegetation.

8.7.4.2 Methods

General vegetation condition is monitored through the use of aerial photogrammetry including color-infrared and color film taken by fixed wing aircraft. Direct field observations and recording will also be utilized.

8.7.4.3 Experimental Design and Data Analysis

Flights utilizing color infrared will be made every year; those utilizing color will be obtained every five years. Aerial photographs will be used to monitor the physical changes which occur as the result of development and to detect any physiological stress which might occur.

No specific hypothesis is to be test statistically as part of this program because there are no specific limits on interpretations of aerial photographs. The purpose of the program is to evaluate the overall condition of the vegetation at a more general level than the other monitoring programs.

The photographs from the air photo surveys will be examined for any anomalous vegetation patterns during development monitoring compared to those taken during the baseline and prior data collection periods.

8.7.5 Microclimatic Studies

8.7.5.1 Objectives and Rationale

In order to define changes in plant growth and wildlife populations the micro-climatic parameters which affect plant growth and wildlife populations are studied.

8.7.5.2 Methods

In addition to the extensive meteorology study, Section 6.3, micro-climatic stations are monitored. Studies on micro-climatic parameters on the C-b Tract provide data that are useful in assessing changes in vegetation production and structure, animal populations, or animal activity patterns, and may also be correlated with changes in functional components of the C-b ecosystem that may occur as a result of shale oil development.

8.7.5.3 Experimental Design and Data Analysis

Five micro-climatic stations are located in development sites and five in control sites. The locations of these ten sites (see Fig. 8.1-1) are the same as baseline locations. Therefore, data from March 1975 through the present can be compared. Each station is monitored twice monthly for the following parameters:

Mc Station Locations	Parameters
No. 1 Chained Pinyon-juniper Rangeland, Veg. Plot 1	Air Temp.: 1 m
" 2 Chained Pinyon-juniper Rangeland, Veg. Plot 2	Soil Temp: Surface
" 3 Plateau Sagebrush, Veg. Plot 3	
" 4 Valley Bottom Sagebrush, Veg. Plot 4	Precipitation
" 5 Pinyon-juniper Woodland, Veg. Plot 5	Snow Depth and Moisture Content
" 6 Pinyon-juniper Woodland, Veg. Plot 6	
" 7 Chained Pinyon-juniper Rangeland (Animal Trapping Transect)	
" 8 Bunchgrass Community, South-facing Slope	
" 9 Valley Bottom Sagebrush, Mouth of Sorghum Gulch	
" 13 Mixed Mountain Shrubland, North-facing Slope	

All temperature readings consist only of maximum and minimum readings for two-week periods. Precipitation will be measured only during the growing season, March through October. Therefore, precipitation data from meteorology stations 020 and 023 are utilized for winter-month readings (November - February) for valley and pinion-juniper microclimate stations. Snow measurements are obtained approximately from November - February.

The hypotheses to be tested in this analysis (Table 8.1-2) are:

> H_0: No statistical difference exists in temperature readings over time between sites.
>
> H_0: No statistical difference exists in total precipitation over time between sites.

Statistical analysis used to examine changes in these plant-growth and wildlife parameters in the vicinity of Tract C-b will include monthly time series and correlation with plant and wildlife data.

8.8 Threatened and Endangered Species

Peregrin falcons have been sighted several miles to the south of C-b. Greater sandhill cranes have been observed several miles to the east on Piceance Creek. Even though bald eagles are occasionally seen on or around the Tract, no nests have been observed on or near the Tract and C-b development should not affect them since C-b is only at the southern end of their wintering range in the White River drainage. Because the C-b project is not expected to affect the areas where sightings have been made, a specific program for endangered species has not been included in the developmental monitoring program. Presence of any of these three endangered species is monitored.

In conjunction with the numerous biological studies that will be conducted on and near Tract C-b during all parts of the year, observations confirmed by staff field biologists of any threatened or endangered species will be reported to the AOSO. Appropriate studies to determine significance of a sighting will then be initiated as determined jointly by C-b personnel and AOSO.

8.9 Revegetation

Revegetation monitoring will be conducted on sites which have undergone surface disturbance and on raw shale disposal sites. These sites, approximately 40 in number, are delineated in the Erosion Control and Rehabilitation Plan. Monitoring techniques will assess the progress of re-established vegetation through determination of cover and productivity of species groups and entire sites. Parameters to be studied on disturbed and disposal sites include species frequency and cover for forbs, grasses, and shrub and tree seedlings; cover by litter, soil, rock, mosses, and lichens; and herbaceous standing crop for annual and perennial grasses and forbs.

8.9.1 Vegetation Structure and Composition

8.9.1.1 Objectives and Rationale

Vegetation structure and composition on revegetated disturbed sites will be monitored in order to evaluate the general success obtained in re-establishing vegetation on these sites. Specific attention will be given to the changes in species present, cover, and productivity as a function of time, to determine range condition toward succession or regression.

8.9.1.2 Methods

Each disturbed site will be sampled once each year at the peak of the growing season. Sampling adequacy will be determined by size of the disturbed area. Sampling will include determination of species frequency; % cover by species; and % cover by litter, soil, rock, mosses, and lichens. Herbaceous species and shrubs less than 0.25 m in height will be sampled.

8.9.1.3 Experimental Design and Data Analysis

Ten 1-centare quadrats will be permanently located at each disturbed site greater than an acre in size. Percent cover by species, litter, soil, rock, mosses, and lichens will be estimated.

The following hypotheses will be tested in this analysis (Table 8.1-2):

H_0: No significant change exists in species frequency over time at any given site.

H_0: No significant change exists in annual species cover over time at any given site.

Unlike the other null hypotheses set forth for developmental monitoring where no change is seen as the lack of oil shale impact, no change or difference is viewed in revegetation as undesirable (in most cases). Revegetation is viewed in terms of changes or succession, towards an eventual desired plant cover. Therefore accepting null hypotheses in revegetation is a statement for further work and a lack of success in the revegetational programs. After a number of years, however, when an acceptable vegetation type is obtained, one would expect to reject the null hypotheses. A significant change is difficult to define because change is expected; therefore a significant change will be determined using professional judgment on the part of reclamation specialists from AOSO and C-b based on baseline data from comparable control sites. Evaluations will be limited to areas greater than 1 acre. Dry weights will be the reported clipped weights.

Frequency and cover data will be analyzed using non-parametric methods, such as a paired sign test or paired t-test. Data will be evaluated using professional judgment and baseline data from comparable control sites. Sites will also be compared in a subjective manner for differences in any given year or between years. Also, sites will be evaluated for differences compared to control areas of similar vegetation types.

8.9.2 Productivity

8.9.2.1 Objectives and Rationale

Herbaceous standing crop on disturbed sites will be measured in order to determine successive changes in this parameter over time and to evaluate the productivity of these sites.

8.9.2.2 Methods

Each disturbed site will be sampled once each year during peak growing season. Sampling will include clipping of the following herbaceous fractions: perennial forbs and grasses, annual forbs and grasses.

8.9.2.3 Experimental Design and Data Analysis

At least five 1-square meter plots will be located in each disturbed site and clipped at ground level. Clipped fractions will be separated according to the fractions described above. In addition to the clipped plots, 50 1-square meter plots (including the 5 clip plots) will be estimated by the ocular method at each site. This method constitutes the double sampling technique. Fractions will be bagged and weighed separately to determine standing crop expressed in kg per hectare for the individual fractions and the total clipped sample. The combined data from clipped and ocular data will be used to generate a regression line in order to adjust the ocular estimates (Wilm 1944).

The following hypotheses will be tested in this analysis (Table 8.1-2):

H_0: No significant change exists in standing crop over time at any given site.

H_0: No significant difference exists in standing crop over time between sites.

As in the previous section on vegetation structure and compositon, a significant difference is based on professional judgment and baseline data from comparable control sites. Evaluations will be limited to areas greater than 1 acre. Dry weights will be the reported clipped weights. Standing-crop data will be subjected to analysis of variance techniques in order to determine

the significance of year-to-year changes in any given site (at $\alpha = .10$) or between sites, and to determine the differences between sites during any given year.

8.9.3 Demonstration Plot

In 1979 an experimental plot will be constructed to test the reclamation methodology planned for raw shale disposal embankments. Plant species, fertilization, mulches, and irrigation will be tested. Half the plot will be irrigated with 1 acre-foot of water over a two-year period, the other half will not be irrigated. Both sides will have independent impermeable drains to collect any leachate. The leachate will be compared with rainfall to determine effects on water quality from an embankment of 18" of soil-like material over raw shale. Parameters to be sampled will be the same ones which are important for hydrology program, Section 5.2, with regard to impoundments.

8.10 Systems Dependent Monitoring

It again needs to be emphasized that systems dependent programs occur only if "triggered" by the indicator variables above the selected threshold level.

8.10.1 Aquatic Ecology

8.10.1.1 Objectives and Rationale

If significant differences in water quality, periphyton or benthos are observed, over time or between control and treatment sites, and the differences can be attributed to oil shale development, then a fish sampling program will be initiated.

8.10.1.2 Methods

Sampling will be done at the same locations as was done for baseline data collection. Variables that would be measured are: general condition, length, weight and reproduction condition. Tissue analysis may be needed.

8.10.1.3 Experimental Design and Data Analysis

Electrofishing and seining methods would be used for collecting fish, similar to baseline methods.

Correlations will be made between collections from control and developmental stations, baseline data, and data from the ongoing water quality, periphyton and benthos studies.

The hypotheses to be tested will be determined when this program is initiated.

Statistical analyses used to examine any possible changes in the fish population in the Tract vicinity could include some non-parametric procedures and chi-square tests along with analyses of variance and correlation.

8.10.2 Sublethal Biochemical Studies

If significant differences in herb production, composition or general conditions are observed over time, or between developmental and control plots, it may become advisable to sample the accumulation of pollutants in plant tissues. These studies could also begin if there is reason to believe that toxic elements have been introduced into the system (high levels of air emissions, irrigation water of poor agricultural quality, etc.) and that these toxins would be accumulated by plants. The study of sublethal biochemical parameters is designed to detect early changes in the concentration of potentially harmful substances which may in time adversely affect primary productivity. Early detection of toxins at sublethal levels in the primary producers will aid in preventing the spread of these toxins throughout the food chain. Experimental design details vary with vegetation type, pollutant, etc.; therefore, selection of methods and elemental analysis will be based on pollutants detected at air quality trailers when this system-dependent operation is initiated.

8.10.3 Soil Plant Elemental Analysis

8.10.3.1 Objectives and Rationale

Toxic elements enter the food chain via transport media (air, water, and soils), are often absorbed and accumulated by lower trophic levels and move up the food chain through higher trophic levels. A baseline analysis has been conducted by Zuccaro (A Trace Element Survey of Surficial Materials on Colorado Oil Shale Tract C-b and Vicinity, Rio Blanco County, Colorado. December 4, 1978, Colorado School of Mines.) A future follow-up analysis can be undertaken if trends toward toxic levels are noted. Toxins in soils may also affect microbial activity, thus affecting decomposition, a most vital function in the ecosystem. It is to be noted that further research is necessary to determine availability of mycorrihizal tests and applicability.

8.10.3.2 Methods

Samples will be collected randomly from the four major vegetation types: pinyon-juniper-woodland, chained pinyon-juniper, upland sagebrush, bottomland sagebrush. Soil samples will be collected at rooting depth (10-15 cm). Vegetation samples will include the four major plant species from each vegetation type. Sample collection, storage and preparation will follow Methods in Plant Ecology (Chapter 8, Chapman 1976). Analysis will be accomplished using standard laboratory techniques.

8.10.3.3 Experimental Design and Data Analysis

Before commercial activities begin, soil and vegetation samples will be collected from control and developmental areas from the four major vegetation types. These preliminary collections will establish further baseline for future comparison, in addition to the School of Mines test.

Plant tissues will be analyzed for these possible pollutants: SO_2, NO_x, fluoride chlorine, copper, zinc, cadium, mercury, boron, barium, calcium, arsenic, selenium and molybdenum.

Soil collections will be analyzed for: fluoride, chlorine, copper, zinc, cadium, mercury, boron, barium, calcium, sulfur, arsenic, selenium, molybdenum, nitrogen compounds, pH, and conductivity.

The following hypotheses will be tested:

H_0: No significant difference exists in the concentrations and composition of potentially toxic elements in soils and vegetation over time.

H_0: No significant difference exists in the concentration and composition of potentially toxic elements in soil and vegetation between control and developmental monitoring sites.

Hypotheses will be tested at the 0.10 level of significance, using a t-test and analysis of variance. Trend analysis may be useful to test the hypothesis over time.

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9.0 ITEMS OF HISTORIC, PREHISTORIC OR SCIENTIFIC INTEREST

9.1 Objectives and Scope

The objectives are to establish and maintain a program of continuing observation for items of historic, prehistoric, or scientific value during construction and tract operations as required by Section 6 of the Oil Shale Lease Environmental Stipulations.

9.2 Planned Actions

The on-tract coordinator shall inspect all activities which might cause a disturbance of the land surface as often as is necessary to prevent disturbance or destruction of items of historic, prehistoric or scientific interest. Should such an item or items be uncovered, all activities causing further disturbance shall be halted and a report made to the Environmental Services Manager, who shall forward such report to the Area Oil Shale Supervisor. Where a question exists as to whether or not an object is of historic, prehistoric, or scientific interest or is an object of antiquity, activity shall be halted and an archaeological specialist will determine its significance and a report made to the Area Oil Shale Supervisor for a final determination.

New employees will be briefed on lease stipulations, ecological parameters to be studied, the significance of monitoring areas and material on nature of historic or scientific values. A tape-slide presentation is being developed over the next few months on this material. Hopefully this will eliminate unnecessary disturbance and data loss.

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10.0 INDUSTRIAL HEALTH AND SAFETY

Periodic reports on Health and Safety Activities have been requested by the Area Oil Shale Supervisor. Such reports are those prepared by the C-b Project and all contractors for distribution to outside Federal and State agencies, i.e., Mine Safety and Health Administration (MSHA) and the Colorado Division of Mines and inspection reports made by these agencies and received by the Project and all contractors at the C-b site.

These reports relate to accident frequency analyses, inspection reports and responses, health and safety training, and variance reporting. As received, they are included in the semi-annual data reports.

10.1 Accident Frequency Analysis

Included here are quarterly employment data, industrial illnesses and injuries and accident frequency analysis. Quarterly employment reports are submitted by the operator to MSHA within 15 days of the end of the quarter. Injury reports are required within 10 days after the injury.

The C-b quarterly employment report contains the average number of persons working for the quarter at the mine, total man-hours worked and total number of injuries and illnesses. A quarterly report is issued by MSHA which includes the cumulative disabled injury frequency rate defined as:

$$\frac{\text{Number of disabling injuries} \times 1{,}000{,}000}{\text{Man-Hours Worked}}$$

10.2 Inspection Reports and Responses

These include inspection reports by the State of Colorado Bureau of Mines and MSHA. They may cite actions that, in their opinion, are required to comply with regulations. C-b responsive comments on the disposition to citations (abated or reason not abated) are noted on the reports, as appropriate.

10.3 Health and Safety Training

MSHA Health and Safety Regulations were published in the July 18, 1978 Federal Register. The C-b Health and Safety Plan was submitted on January 11, 1979 and is expected to be approved within 60 days of that date; the approved plan must be implemented within 60 days of the date of approval. A copy of the approved plan will be submitted to the AOSO and included in the semi-annual data report.

10.4 Variance Reporting

No variance is currently required by MSHA or exists at the C-b Tract.

10.5 Gas Monitoring

During shaft sinking operations hand-held field instruments will be used to monitor for both H_2S and methane at specific time intervals. These monitoring intervals will start immediately upon re-entry after blasting and before going to work at the start of each shift. Should the presence of either of these two gases be indicated, the sampling frequency will be increased accordingly.

Gas sampling during horizontal development work will be defined at a later date using in part the experience gained during shaft sinking.

Records of samples taken will be kept in a log book at the hoist house. Values significantly above zero will be included in the data reports to the AOSO.

11.0 SUBSIDENCE MONITORING

The overall objective of the subsidence monitoring program is to determine the effects of underground excavations on the ground surface and on in-situ mining levels.

The surface and underground subsidence caused by mining activities cannot start until significant underground development out from the shaft pillar areas occurs. The monitoring facilities described below are to be in operation before the rubblization blasts for the room module in the ancillary development occur, and before the initial rubblization blast in the commercial development.

A potential method of analysis of the subsidence data is outlined below. Specific details of the exact analysis procedures cannot be provided until the mining plans and surface facilities are fixed by our continuing design effort.

11.1 Potential Analysis Methods

11.1.1 General

Determination of the measurement intervals for subsidence measuring instrumentation and evaluation of accuracy or precision of the measurement systems are described here.

A normalization interval will be run for all the subsidence monitoring systems to determine the precision of the procedures and results. For it, the measurements will be repeated to determine the variability of instrument readings, i.e., the accuracy of the mechanical parts themselves and variability effects of outside conditions. This so-called system variability is found by graphically or numerically comparing results from the same station or location. For example, in a precise level network, the absolute elevations of individual stations are plotted. A comparison of the plots gives an assessment of the variability or "error" in the system. This defines the magnitude of "real" changes, when they occur. An "error" analysis must be made for each monitoring system installed.

The initial phases of the program require two to ten or possibly more complete system measurements until outlier readings are at an adequate level. The measurements are planned at yearly intervals for stable regions and at 1 - 2 month intervals in active mining areas.

11.1.2 Specific

The main parts of the subsidence monitoring program are concentrated on the surface and will consist of the measurement of vertical dimension changes, horizontal dimension changes and tilt (in the shaft pillar area).

All the methods will interpret data-through-time versus displacement plots or numerical analysis of these displacements. The direct examination of such data is a most sensitive method to determine trends and absolute change.

Derived data processing such as the velocity (time rate of change of the displacements) and acceleration (time rate of change of the velocity) will also be used to define changes in the movement regimentation of the monitoring systems. Portions of the data processing may be computerized to decrease the direct labor of data processing.

Further details of the monitoring plan are outlined below.

11.2 Surface Monitoring Effort

11.2.1 Leveling Techniques for Vertical Displacements

1) Organization of grid(s) over surface area(s)

   a. Two Retort Ancillary Phase Development

      i. Two mutually-perpendicular level lines meeting at the center of the module.

      ii. Level stations at approximately 100 feet spacing.

      iii. Base control run to stable ground at each of level lines.

      iv. The control lines are expected to extend approximately 240 feet beyond the mining development, corresponding to our estimate of the arch distance or distance to stable ground.

   b. Four Retort Module Ancillary Phase Development

      i. Same as the two retort module

   c. Commercial Development

      i. Parallel level lines are to be established along the barrier pillars and along the middle of the panel.

      ii. Level stations are to be installed at approximately 100 foot intervals along the level lines.

      iii. Cross links between lines will be established at 300 foot intervals with individual stations at approximately 100 foot intervals.

2) Equipment and Procedures for use in the Level Surveys

   a. A self-leveling engineer level, optical micrometer and invar staves will be used for measurements.

   b. Normal differential-leveling surveying techniques will be used to minimize errors.

   c. Permanent, standard level monuments will be used to alleviate surface effect due to moisture and temperature.

   d. The expected accuracy of single measurements are on the order of 0.0005 foot.

3) Leveling surveys will also be run during mine dewatering to measure elastic subsidence due to drop in water level.

11.3 Underground Monitoring Effect

No extensive underground monitoring systems are proposed because of two factors. The first factor is the hostile environment of the underground mining areas, and the general difficulties in maintaining a research-academic program which provides no benefit to the mine operations. The use of the mine underground surveying network alleviates many of the above problems and provides a three dimensional system from which pillar strains, shortening and tilt, etc., can be calculated. The second factor is that most subsidence effects will decrease with depth and will no longer exist at the retort bottoms. It is therefore prudent to concentrate the subsidence monitoring effect at the ground surface and to utilize the required underground surveying network for underground data.

11.3.1 The mine surveying network will be utilized to determine vertical and horizontal displacements on all mining levels.

11.3.2 A re-survey of the underground survey network will be undertaken at yearly intervals and changes in vertical and horizontal disturbances tabulated.

11.4 Distance and Angle Measurements for Horizontal and Vertical Displacements

11.4.1 Distance and Angular Measurements

1) Distances are to be measured with an electronic distance-measuring device from selected "base" stations.

2) Angles are to be measured with a theodolite (one-second accuracy) from selected "base" stations.

3) Adequate primary, secondary and tertiary "base" controls will be established to determine horizontal changes between level stations established in Item 11.2 above.

11.4.2 Equipment and Procedures for Use in Distance and Angular Surveys

1) An electric distance-measurement device and accessories will be used to measure distances.

2) A theodolite (one-second accuracy) will be used for angular measurements.

3) A permanent triangulation network will be established on stable ground and maintained for the project life.

11.5 <u>Aerial Photography to Inventory the Physical Features of the Site</u>

11.5.1 1/6000 scale photography is utilized to inventory site physical condition. This photography occurs at yearly intervals in black and white. It is the same photography as in Section 3.2.

11.5.2 1/1000 scale photography is utilized over the entire tract as well as over active mining and other disturbed areas.

1) To provide the details of subsidence-caused effects on the surface.

2) Photograph at yearly intervals to cover areas mined in the previous two years and to cover mining to be undertaken in the next year.

11.5.3 Equipment and Procedures for Aerial Photography

1) Use standard air photo techniques to produce stereo pairs and controlled mosaics.

2) Field premarking is to be established for the project life and renewed annually before photographing.

3) The photographs should be taken at the same time each year in the spring.

11.6 Specific Monitoring in the Shaft Pillar Areas

11.6.1 Level Lines for the Shaft Pillars

1) Two lines at right angles across each shaft pillar which will extend into the rubblized areas.

2) Level stations are established at approximately 100 foot intervals.

11.6.2 Tiltmeter in the Shaft Pillars

1) Establish five tiltmeters in each shaft pillar. One tiltmeter is located in each quadrant of the pillar near the boundary with rubblized rock. The fifth tiltmeter is located near the shaft pillar center.

11.7 Surface Vibration Measurements

11.7.1 Three continuous-reading accelerometer stations will be established at widely spaced intervals at surface.

11.7.2 Accelerometers will be mounted on concrete pads coupled to bedrock. Location on stable ground is not influenced by rubblized retorts.

11.7.3 Data from accelerometers will provide a quantified assessment of the magnitude and duration of the rubblization blast-induced vibrations. In addition any earthquakes that might be induced on site will be pinpointed.

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12.0 ECOSYSTEM INTERRELATIONSHIPS

Indicator variables for Development Monitoring are given on Table A-1 of the appendix; this table also lists perturbations that affect the magnitude of these variables and the environmental consequences (or impacts) of these perturbations. Examples of perturbations include mining, retorting, shale disposal, waste disposal, etc. Environmental consequences may affect other indicator variables; such relations of indicator variables with other indicator variables are to be analyzed in Development Monitoring and are called ecosystem interrelationships.

Ecosystem interrelationships are not monitored or measured directly. They are inferred from three principal techniques: expert judgment resulting from baseline observations of two or more variables, correlative statistics and predictive ecosystem modeling. Aspects of all three have been gleaned from the baseline studies and reported in Volume 5, System Interrelationships, Environmental Baseline Program Final Report and its Appendix F, User's Reference Diagrams (1977). In particular, baseline judgment has been utilized to obtain a) potential impacts of oil shale development (Table 4-1 of the above reference and reproduced here as Table 12.0-1) and b) a comprehensive "effects matrix" (Figure 5-7 of Appendix F of the above reference).

Regarding Table 12.0-1 potential impacts are shown for categories of air-air (i.e., influence of air emissions on ambient air concentrations), air-water, air-soil, air-vegetation, air-wildlife, noise-noise, and noise-wildlife. Perturbations are listed by phase of operation.

With regard to the comprehensive "effects matrix," so-called effect generators (driving variables, perturbations, state variables)are listed across the top (matrix columns) and effect receptors (abiotic and biotic components and processes) are listed at the side as matrix rows. Entries in the matrix are the following interrelationships: direct effects, indirect effects, both direct and indirect, and effects of particular concern. These 45 updated effects of particular concern have been transposed to Table 12.0-2 of this report. They may be considered candidates for future predictive ecosystem models. To date the ecosystem modeling in Volume 5 has been conceptual only; a complete ecosystem computer model is judged to be beyond the scope of the project.

The interrelationships of Tables A-1, 12.0-1, and 12.0-2 and others defined as new monitoring results are analyzed in the future are to be subjected to correlative statistical techniques so as to define those of major concern. Subsequent monitoring can then concentrate on these.

12.1 Predictive and Correlative Statistical Techniques

These statistical techniques will be used in correlations among parameters and forecasting trends and environmental impacts resulting from oil

Table 12.0-1 POTENTIAL IMPACTS OF OIL SHALE DEVELOPMENT ACCORDING TO PHASE OF OPERATION

	Potential Impacts	Perturbations	Site Prep./ Pre-Construction	Pre-production Mining	Ancillary Facilities	Commercial Facilities Construction	Commercial Operation
I.	Air-Air	a. Air Pollution from Oil Shale Plant (Temporal/Spatial)					
		SO_2			x		x
		Particulates	x	x	x	x	x
		NO_2			x		x
		NMHC			x		x
		CO			x		x
		Oxidant			x		x
		Reduced Visibility			x		x
		Odors			x		x
		Water vapor/Stream releases/Icing/Fog			x		x
		b. Air Pollution in Traffic Corridors					
		NO_x	x	x	x	x	x
		CO	x	x	x	x	x
		THC	x	x	x	x	x
		Fugitive Dust	x	x	x	x	x
		c. Air Pollution from Mine					
		H_2S			x	x	x
		CO		x	x	x	x
		Mine Dust		x	x	x	x
		THC		x	x	x	x

Table 12.0-1 (CONTINUED)

Potential Impacts	Perturbations	Site Prep./ Pre-Construction	Pre-production Mining	Ancillary Facilities	Commercial Facilities Construction	Commercial Operation
II. Air-Water	a. Water Pollution from Fugitive Dust		x	x	x	x
	b. Trace Elements in Surface Waters from Air Emissions					
	Arsenic			x	x	x
	Mercury			x	x	x
	Selenium			x	x	x
	Others			x	x	x
III. Air-Soil	a. Fugitive Dust					
	Construction, Power & Pipe Lines		x	x	x	
	Haulage Roads		x	x	x	
	Shale Piles			x	x	x
	b. Trace Element Fallout from Air Emissions			x		x
IV. Air-Vegetation						
	a. Pollution Dose Effects on Vegetation					
	Ozone			x	x	x
	Synergistic Effects SO_2+O_3, SO_2+NO_2			x	x	x
	Influence of Removal Processes			x	x	x
	Trace elements			x	x	x
	b. Pollution Isopleths-Patterns in Space					
	SO_2			x		x
	Particulates			x		x
	Oxidant			x		x
	Locations of Bio-control Plots			x		x

Table 12.0-1 (CONTINUED)

Potential Impacts	Perturbations	Site Prep./ Pre-Construction	Pre-production Mining	Ancillary Facilities	Commercial Facilities Construction	Commercial Operation
V. Air-Wildlife						
	a. Purely Climatological Effects on Populations	x	x	x	x	x
	b. Possible Pollutant Isoplath Influence			x	x	x
VI. Noise-Noise						
	a. Noise Pollution					
	Construction Activity	x	x	x	x	x
	Traffic Corridors	x	x	x	x	x
	Oil Shale Plant			x	x	x
	Mine		x	x	x	x
VII. Noise-Wildlife						
	a. Population Relocation	x	x	x	x	x
	b. Stress	x	x	x	x	x

TABLE 12.0-2

MAJOR ECOSYSTEM INTERRELATIONSHIPS

EFFECT RECEPTORS / EFFECT GENERATORS	PRECIPITATION	AIR TEMPERATURE	BORON (Water)	SO_2 (Air)	NO_x (Air)	OZONE (Air)	FLUORIDE (Water)	TRACE ELEM. (Air)	NOISE	DISTURBED VEG.	UNREVEG. BARE AREAS	EROSION	MIXED SOIL PROFILE	ALTERED SOIL CHEM.	SEDIMENT	ALTERED SURF. WATER FLOW	WATER TABLE ALTER.	ALTERED WATER QUAL.
RUNOFF	X										X	X			X			
STREAMFLOW												X					X	
GROUNDWATER FLOW																	X	
PLANT GROWTH	X	X	X	X	X	X	X	X						X		X		
LITTER DECOMP.				X														
ANIMAL GROWTH	X	X	X				X	X										
REPRODUCTION									X									
ANIMAL MOVEMENT									X									
AQUATIC PLANT GROWTH			X				X								X	X		X
AQUATIC VERT. GROWTH															X	X		X
AQUATIC VERT. MORT.																		X
AQUATIC INVERT. GROWTH															X	X		
AQUATIC INVERT. MORT.																		X
SOIL CHEM. & pH								X										
WATER QUALITY																	X	
ANIMAL TISSUE							X											
GEN. HABITAT									X	X	X							
REVEGETATION													X	X				

shale development and production: multiple linear regression, partial correlation among interacting parameters, and time series. They utilize the computer, an environmental data base, and some specialized computer models. Examples of these techniques are contained in the Appendix. Multiple linear regression and partial correlations are well known. Time series analysis as planned for monitoring utilizes a computer model based on the Box-Jenkins techniques as documented in Time Series Analysis Forecasting and Control, revised edition, George E. P. Box and Gwilyn M. Jenkins, Holden - Day (1976), and A Computer Program for the Analysis of Time Series Models Using Box-Jenkins Philosophy by David J. Pack (1977). This program provides for interactive control of the inputs and outputs and for selection of the appropriate time series model from the data base. Single time series may be analyzed or multiple series models correlated with each other. The primary applications of time series analysis are (1) for first forecasting future trends in a single parameter as identified from past data and (2) attempts to correlate two-or-more parameter series with each other; initially, specific project applications will concentrate on the former.

12.2 Ecosystem Models

In 1979, no further development of an aggregated ecosystem model is planned. Time series analysis results should prove a valuable precursor to such development.

Population dynamics of the mule deer population in the vicinity of C-b are to be simulated primarily for road-kill mitigation studies on an operational model utilizing two-sex Leslie matrices (Fosdick 1974). "Hunting" is simulated via an arbitrary hunting matrix which accommodates hunting by age, class and sex. Road kills are studied as a form of "hunting." Effectiveness of many mitigative measures are to be studied via this technique and include vehicle speed reduction, deer fences with underpasses, range improvements, mass transit, warning lights, mirrors, and traffic scheduling and possibly others. Age and sex-specific mortality and age-specific natality estimates are in process. More details of this model are presented in the Appendix.

13.0 DATA MANAGEMENT AND REPORTING

13.1 Data Management

It is intended that baseline data (on indicator variables of Development Monitoring) be entered into Occidental's computerized data management system called RAMIS. Similarly Interim and Development Monitoring data are entered into RAMIS. RAMIS allows flexible report generation and interface with statistical computer programs. Baseline air quality data tapes have been furnished to the AOSO for eventual incorporation into EPA's SAROAD data base. Tapes of the data base for Development Monitoring indicator variables will be furnished to the AOSO. Similarly USGS stream gauging data from C-b are available for incorporation into STORET.

Extensive data analysis matrices have been included in Sections 5.0, 6.0, 7.0, and 8.0. These matrices have identified the environmental variables to be analyzed and summarized the hypothesis tests and associated analytic technique to be used for each study. Table 13.1-1, Summary of Monitoring Plan Analytic Techniques extracts from the data analysis matrices the statistical and analytic techniques that are planned. For each of these identified techniques (Statistical Problem), the common test name is shown, the usual level of significance for the test, and the typical null hypothesis associated with it. The applicability of the technique to the specific Monitoring Plan study is shown by an "X" in the study subsection column on the right side of the table.

13.2 Reporting

An Annual Report will be issued each year on the anniversary date of the lease. Thus the first annual report is due on April 1, 1979. Biology, air quality and meteorological data are reported by the seasonal year (Dec 1 - Nov 30) and hydrologic data by the water year (Nov 1 - Oct 21). For comparisons with annual standards (e.g., air quality) the calendar year is required.

The annual report summarizing the analyses of available data includes: graphical, tabular and statistical analyses related to the hypotheses stated in this report, including analyses from Baseline related to verification of long-term trends for principal indicator species.

Semi-annual data reports will be issued as follows:

Reporting Period	Issue Report Date
Dec through May	July 15
June through Nov	Jan 15

Data lags may exist as a result of these 45-day issuance dates after the end of each 6-month period.

A second purpose of the Annual Report is to document intended Development Monitoring Program changes for the subsequent year of monitoring. Quarterly meetings for program review (Dec, Mar, June, and Sept) are to be held at the AOSO; at such meetings proposed program changes can be discussed.

TABLE 13.1-1

SUMMARY OF MONITORING PLAN ANALYTIC TECHNIQUES

NUMBER	STATISTICAL PROBLEM	STATISTICAL TEST	USUAL LEVEL OF SIGNIFICANCE	TYPICAL NULL HYPOTHESES
1.	Comparison of two means	T-Test	.05	Null Hypothesis - A hypothesis expressing no difference or no change in means.
2.	Comparison of multiple means	Newman-Keuls or Analysis of Variance	.05 .05	Null Hypothesis - Stating that all means are equal.
3.	Comparison of two proportions or ratios	T-Test	.05	Null Hypothesis - There is no difference between the proportions or ratios.
4.	Comparison of multiple proportions or ratios	Log-likelihood ratio Kolmogorov-Smirnov	.05 .05	Null Hypothesis - Stating the ratios or proportions are equal.
5.	Comparison of sample distribution of proportions to expected dist. of proportions.	Log-likelihood ratio Chi-Square	.05 .05	The sample distribution of proportions is no different than expected.
6.	Relative measure of diversity of observed attribute or phenomena.	Shannon index of diversity	NA	Not Applicable - Relative measure of predictability of phenomena.
7.	Goodness of fit of set of observations to expected set.	Chi-Square Log-likelihood Kolmogorov-Smirnov	.05 .05 .05	Null Hypothesis - There is no difference between observed data and expected data.
8.	Correlation between two variables.	Confidence Interval for coef of corr-R	.95	The observed value of one variable is independent of the other variable.
9.	Partial correlation between three or more variables.	Confidence Interval for $R_{ij.k}$	.95	The observed correlation between variables i and j is explained by high dependence of i and j on variable k.
10.	Determination of trend in observed data over time.	Slope of regression equation	.05	Null Hypothesis - Regression of variable on time has zero slope.
11.	Determine time series single variable model and auto-regressive moving average parameters	Fit of model to data	.05	Time series is stable. The mean is best forecast of future values.
12.	Determine time series intervention model and forecasting parameters.	Determine forecasting function that includes forced fit to pre-determined values.	NA	Not Applicable - Significant relationship is assumed and function is determined.
13.	Multiple simple correlation and linear regression.	Determine simple multiple correlation matrix and linear regression coefficients of several variables on dependent var.	.05	There are no correlations between any pair of variables. There are no significant regression coefficients.
14.	Tabulation of relevant data in summary form	Not Applicable	NA	Not Applicable
15.	Scatter diagrams of observed data	Not Applicable	NA	Not Applicable
16.	Histograms comparing several summary parameters	Not Applicable	NA	Not Applicable
17.	Graphs displaying parameters as function of time.	Not Applicable	NA	Not Applicable
18.	Special purpose models	Not Applicable	NA	Not Applicable
19.	Non-parametric methods	Paired Sign	.05	No change has occurred Frequency, Density, or Cover.
20.	Maps	Not Applicable	NA	Not Applicable

MONITOR PLAN SECTION

NUMBER	5.2						5.3					6.2			6.3		6.4		7.2		8.2					8.3		8.4	8.5			8.6		8.7					8.8		8.9		12.0	
	1	2	3	4	5	6	1	2	3	4	5	1	2	3	1	2	1	2	1	2	1	2	3	4	5	1	2	1	1	2	3	1	2	1	2	3	4	5	1	2	1	2	1	2
1.																					X					X								X		X		X			X			
2.																					X								X	X			X	X	X									
3.																									X							X	X											
4.																						X	X	X		X	X				X		X											
5.																												X								X		X			X			
6.																X												X				X	X											
7.																																												
8.							X	X	X					X																			X			X		X						
9.														X		X																	X										X	
10.																																		X										
11.	X	X				X	X	X	X			X	X	X	X					X		X																X						
12.	X	X					X	X																														X					X	
13.	X	X				X								X		X		X																									X	
14.	X	X			X	X	X	X	X			X	X	X	X	X	X		X	X	X	X	X	X			X	X	X	X		X	X	X				X			X	X		
15.												X		X	X																													
16.												X	X			X			X	X		X	X																					
17.	X	X			X	X	X	X	X				X	X	X	X	X		X	X	X	X	X			X	X	X				X	X	X	X	X		X			X	X		
18.																X		X					X		X																			X
19.																																		X							X			
20.																																					X							

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A P P E N D I X

This Appendix consists of two parts a) the Indicator Variables of Chapter 4 which are presented on Table A-1 and b) examples of statistical and simulation techniques utilized in Development Monitoring Analysis as follows:

TABLE A-1

INDICATOR VARIABLES FOR ENVIRONMENTAL MONITORING *

	SPECIFIC VARIABLE	PERTURBATIONS IT RESPONDS TO	ENVIRONMENTAL CONSEQUENCES	THRESHOLD VALUE (TV) **	THRESHOLD TRIGGERS THESE			INDICATE WAYS VAR. ARE TIED TO DEVELOPMENT PLAN AND SCHEDULE
					SECONDARY VARIABLES	PRIM. VAR. SAMPLING FREQ. CHANGES	PRIM. VAR. SAMPLING SITES	
	SURFACE WATER (1)							
1.	Surface water flow (streams, springs)(flow in/flow out)	Dewatering, Rainfall, Irrigation	Diminished flow, Aquatic life dies, affects vegetation, have to augment for irrigation loss, animal support diminishes	30% slope in annual trend line.		Monitor more frequently, check ground water levels more frequently		reduced flows due to dewatering
2.	Surface water temperature	High heat flows to surface due to retorting, low flows.	Aquatic life dies, animal use lessens	$\pm 10^{0}$ over or under yearly maximum or minimum		Monitor more frequently, check ground water levels more frequently		reduced flows due to dewatering
3.	Precipitation input (10cm & 40")	Reduced vegetation covering enlarged surface construction activities				Monitor more frequently, check ground water levels more frequently		
4.	Evaporation from water surface	Reduced vegetation covering, increased soil temp. Increased air temp.				Monitor more frequently, check ground water levels more frequently		
5.	Surface water quality (see TABLE 5.2-1)	Accidental discharges, reinjection system leaks, impoundment spills, dump seepage, impoundment seepage		30% slope in annual trend line.		Monitor more frequently, check ground water levels more frequently		
6.	Discharge flow	Amount of flow released from storage reservoir				Mon. more freq, check ground water lev. more freq.		
7.	Discharge water quality (see TABLE 5.2-1) streams, springs, impoundments	Impoundments - water quality of treated water, amt. of dilution - streams, springs-amt of flow, less flow, worse water quality		30% slope in annual trend line.		Monitor more frequently check ground water levels more frequently		discharge from dam and ponds
8.	Snow pack moisture content					Mon. more freq, check ground water lev. more freq.		
9.	Snow melt runoff					Mon. more freq, check ground water lev. more freq.		
10.	Irrigation water	Water quality (Poor)	Vegetation & Wildlife adverse effects			Mon. more freq, check ground water lev. more freq.		mine dewatering: sprinkling
11.	Water potential, upper soil layer	Vegetation cover				Mon. more freq, check ground water lev. more freq.		
12.	Sedimentation (TSS,TDS)	Vegetation cover, construction		30% slope in annual trend line.		Mon. more freq, check ground water lev. more freq.		
13.	Evaporation from soil surface	Vegetation cover, forest cover, construction				Mon. more freq, check ground water lev. more freq.		
14.	Irrigation water flow (shale, pile, mine water)		Surface waters adversely effected			Monitor more frequently, check ground water levels more freq.		runoff during mine raw shale pile growth
15.	Precipitation water quality (reveg. study plot)(TABLE 5.2-1)	Leaching characteristics of raw shale	Poorer Water quality			Monitor more frequently, check ground water levels more freq.		
	GROUND WATER (2)							
16.	Ground water flow (flow in/flow out)	Mining Activities, dewatering	Water table lowered, streams & springs depletion			Monitor more frequently, check ground water levels more freq.		dewatering when lateral drifting starts
17.	Ground water level	Dewatering, reinjection		Wells drop 20% below lowest readings		Monitor more frequently		will be lowered and perhaps depleted
18.	Percolation to groundwater	Amt of precipitation, surface construction	Less percolation, more runoff, less vegetation			Monitor more frequently		
19.	Interlayer infiltration (leachates in shale pile)	Amt of precip, size of raw shale pile	>TDS,TSS in stream flow below dump, poorer water quality in streams			Monitor more frequently		
20.	Ground water quality (see TABLE 5.3-2)	Accidental spills, spent retort leaching, natural leaching		30% slope in annual trend line.		Monitor more frequently		
21.	Water potential, bottom soil layer					Monitor more frequently		
22.	Fluoride, Boron, pH, TDS, Temp, DO	Discharges of poor water quality, - Runoff from construction sites	Fluoride, Boron; plant and animal adverse effects; stream flow; increased turbidity	EPA Standards for discharges State WQCD standards for discharges	increase efficiency of treatment facilities	Monitor and sample more freq.		Floride, Boron and TDS: levels after treatment & impoundment: levels when discharged
	AIR QUALITY (3)							
23.	Temperature (air 30' & 200', surface, soil)	Driving Variable						
24.	Wind (30' & 200') and for soil surface evaporation	Driving Variable						
25.	Relative Humidity	Excessive water vapor from cooling tower	Increase fog, increase potential icing					
26.	Trace metals (Hg, Particulate As, Se, Arsine)	Potential instack emissions	Health hazards	1 std deviation above baseline	Particulate size distribution	Requirements are tied to EPA - PSD Permit.		Instack emissions
27.	SO_2 Ambient Concentrations	Stack emissions, wind	Public health, welfare	30% slope in annual trend line.			1) Poss. Act. extra AQ Sta	
28.	NO_x Ambient Concentrations	Stack, auto emissions, wind	Public health, welfare	30% slope in annual trend line.			1) " " " " "	ancillary & commercial retorts, model validation
29.	HC Ambient Concentrations	Stack, auto mine emissions, wind	Public health, welfare	30% slope in annual trend line.			1) " " " " "	ancillary & commercial retorts, model validation

* Refer back to Chapter 4

** Refer to Section 4.2

TABLE A-1 CONTINUED

INDICATOR VARIABLES FOR ENVIRONMENTAL MONITORING

	SPECIFIC VARIABLE	PERTURBATIONS IT RESPONDS TO	ENVIRONMENTAL CONSEQUENCES	THRESHOLD VALUE (TV)	SECONDARY VARIABLES	THRESHOLD TRIGGERS THESE PRIM. VAR. SAMPLING FREQ. CHANGES	PRIM. VAR. SAMPLING SITES	INDICATE WAYS VAR. ARE TIED TO DEVELOPMENT PLAN AND SCHEDULE
30.	CO Ambient Concentrations		Public health, welfare	30% slope in annual trend line.			1) Poss. Act. extra AQ Sta.	ancillary & commercial retorts, model validation
31.	H_2O Ambient Concentrations	Same as Rel. Hum. above, wind	Public health, welfare, Ice, fog	50% increase in fog days	Salt deposition analysis	Salt deposits	1) " " " " "	ancillary & commercial retorts, model validation
32.	Particulates Ambient Concentrations	Stack, fugitive emissions	Public health, welfare	30% slope in annual trend line.			1) " " " " "	Shale piles anc. & comm. retorts
33.	Particulates Emissions	Plant output level	Public health, welfare; fugitive dust	30% slope in annual trend line.			1) " " " " "	Shale piles anc. & comm. retorts
34.	SO_2 Emissions	Plant output level	Public health, welfare	30% slope in annual trend line.			1) " " " " "	ancillary & commercial retorts
35.	NO_x Emissions	Plant output level; vehicle traffic	Public health, welfare	30% slope in annual trend line.			1) " " " " "	ancillary & commercial retorts
36.	O_3 Emissions	Plant output level; vehicle traffic	Public health, welfare	30% slope in annual trend line.			1) " " " " "	ancillary & commercial retorts
37.	CO Emissions	Plant output level; vehicle traffic	Public health, welfare	30% slope in annual trend line.			1) " " " " "	ancillary & commercial retorts
38.	Noise (on-Tract & Corridors)	Construction, activity level	Wildlife relocates, potential complaints	95% of Colo std	Identify source, noise suppression devices	Increase samples frequently		Directly related to activity
39.	Roadway traffic (area corridor counts)	Construction & ops, schedule	Potential deer road kills	1 std dev above baseline for deer road kills				
40.	Solar radiation, input	Opaque plumes						Plant emissions
41.	Visibility	Opaque plumes, dust, soot	Aesthetics	1 std dev below "Spring" baseline		Decrease freq. to annual		Plant emissions
	BIOLOGY (4)							
42.	A. Terrestrial Animals Deer population (no's, age & sex classes, mortality, natality)	excessive noise & disturbance	reduced natality	Since there are no controls being used for comparing population parameters, no threshold value will be set. Data from these programs, combined with data from the other Tract deer studies and information from the Division of Wildlife, will be used to further understand the dynamics of the deer herd on and surrounding Tract C-b. These population parameters will yield a more complete idea of the deer herd ecology, therefore enabling better analysis of oil shale development impacts.				Construction & Traffic Life of Project
		habitat destruction	loss in carrying capacity & possible decline in numbers (reduced natality)					
		fluorosis	increase in mortality, weakening of general health, reduced natality		fluoride studies, bioassays			
		traffic	increase in mortality, possible shift in adult-to fawn ratio					
		increased hunting pressure	increased mortality, possible shift in sex ratio, and possible reduced natality		Predator sampling	Increase sampling intensity	Control and developmental sites	Increase work force
		increased human contact & activity	overuse of surrounding rangeland					
43.	Habitat utilization and deer concentration locations	habitat destruction and degradation	reduced numbers of deer, weakening of general health, reduced carrying capacity	30% slope in annual trend line.		Increased sampling East and West of the Tract		Should peak upon completion of construction
		Disturbance near key habitats and area of concentration	reduced numbers of deer, (disturbances may prove not to be as large an impact as expected, due to deer habituation)	30% slope in annual trend line.				
		Increased human contact and activity	vegetation vigor declines	30% slope in annual trend line.	More intensive species sampling	Increase sampling intensity	Control and developmental sites	Decrease habitat
44.	Immigration and emigration of deer (movement in and out of Tract)	noise, disturbances, structures, traffic, loss and degradation of habitat	fewer deer on tract	none - treatment and controls would be extremely difficult to establish				Impacts will accelerate with construction and will be an impact for the life of the project. Habituation may lessen the impact.
		Increased human contact and activity	overuse of surrounding rangeland	none - treatment and controls would be extremely difficult to establish	Intensify deer concentrations study	Increase sampling intensity	developmental sites	Increased work force

TABLE A-1 CONTINUED
INDICATOR VARIABLES FOR ENVIRONMENTAL MONITORINC

	SPECIFIC VARIABLE	PERTURBATIONS IT RESPONDS TO	ENVIRONMENTAL CONSEQUENCES	THRESHOLO VALUE (TV)	SECONDARY VARIABLES	THRESHOLD TRICCERS THESE PRIM. VAR. SAMPLING FREQ. CHANGES	PRIM. VAR. SAMPLING SITES	INDICATE WAYS VAR. ARE TIED TO DEVELOPMENT PLAN AND SCHEDULE
45.	Deer migration (movement around Tract)	traffic, altered habitat	altered migration routes, fewer deer on Tract	none - treatment and controls would be extremely difficult to establish				
			overused surrounding areas		Intensify deer concentrations study	Increase sampling intensity	Developmental sites	Increased work force
46.	Coyote population (no's)	loss of habitat, reduced prey base	fewer coyotes (however, coyotes seem to habituate to man and his activities relatively well), increase in prey base	No threshold value will be assigned since there are no controls for comparisons. Professional judgement shall be used to determine significant differences over time. Collection of this data is important to understanding the ecology of Tract C-b, particularly predator/prey relationships.	Increase sampling study	Increase sampling intensity	Control and developmental sites	Impacts will begin with construction and should peak at completion of facilities
		toxic element accumulating in the food chain	reduced numbers through increased mortality and/or decreased natality		Toxin in food chain	bioassay of lagomorphs and small mammals		Toxins, if a problem, should show up in a predator like the coyote further into the project.
47.	Rabbit population (no)	loss of habitat	reduced numbers	30% slope in annual trend line.		increase sampling	Control and developmental sites	Decreased habitat
		toxic element accumulating in plants	weakening in general health, increased mortality, decreased natality					
		traffic	reduced numbers					
		increased hunting pressure	reduced numbers					Pollutants from development get into water and plants
48.	Small Mammal population (no's)	habitat elimination & degradation intro. toxin	reduced numbers, reduced diversity	30% slope in annual trend line.	Intensify study areas	increase sampling intensity		All during construction
		increased work force - contact w/humans incre.	reduced numbers, reduced natality, weakening of general health, reduced diversity			" " "	control and developmental sites	Well into development
49.	Raptor nesting success	habitat elimination & degradation	reduced nesting sites; elimination of habitat for prey base, thereby reducing raptor carrying capacity and nests	none - professional judgement will be used	Intensify study areas	Try to correlate with prey base and nesting throughout the Piceance Basin	Control and developmental sites	Construction and throughtout the life of the project.
		noise and disturbance near nesting sites	abandonment of nests, reduced natality					
50.	Songbird Census	habitat elimination & degradation	reduced numbers & diversity and reduced natality due to loss of nesting areas	30% slope in annual trend line.	Histopathological studies	Increase sampling intensity	control and developmental areas	Throughout construction
		noise and disturbance	reduced numbers & diversity (many species live well with man and his structures, others do not), reduced natality due to disturbance during nesting		Intensify study area			Life of project
51.	Dove Census	same as song birds with the addition of hunter pressure	increased hunter pressure increases mortality	30% slope in annual trend line.	histopathological studies hunter pressure	Increase sampling intensity	control and developmental areas	Beginning with construction for life of the project
52.	Cattle numbers & AUMs (d.v.)	increased cattle numbers, therefore increased grazing	decrease in herbaceous standing live and dead shattering and loss of litter, resulting in moisture loss and reduced production	none		Studies showing herbaceous utilization		Dependent on BLM, whims of ranchers and weather
	(Cattle may be treated as a driving variable that may have a significant impact on the environment or as a variable impacted by oil shale development)							
	Cattle numbers & AUM's (impacted)	habitat destruction & degradation	lowering of carrying capacity and AUM's	none				Throughout construction
		lowering of herbaceous production by air emissions	lowering of carrying capacity and AUM's	none				Well into development
		introduction of toxic element (fluorosis)	weakening of general health, increased mortality	none	histopathological studies			Well into development
53.	B. Aquatic Animals Benthos (no's & biomass)	water quality and sediment degradation, increase in TSS and/or TDS	decrease in biomass and diversity	based on professional judgment because of large annual fluctuations.	Fish (no's, weight, bioassay)	Increase sampling intervals and control & treatment stations to aid in pinpointing source	control and developmental sites	For life of project

TABLE A-1 CONTINUED

INDICATOR VARIABLE FOR ENVIRONMENTAL MONITORING

	SPECIFIC VARIABLE	PERTURBATIONS IT RESPONDS TO	ENVIRONMENTAL CONSEQUENCES	THRESHOLD VALUE (TV)	SECONDARY VARIABLES	THRESHOLD TRIGGERS THESE PRIM. VAR. SAMPLING FREQ. CHANGES	PRIM. VAR. SAMPLING SITES	INDICATE WAYS VAR. ARE TIED TO DEVELOPMENT PLAN AND SCHEDULE
54.	Periphyton (no's & biomass)	water quality degradation, increase in TSS and/or TDS	decrease in biomass and diversity		ish (no's, weight, bioassay)	increase sampling intervals and control treatment stations source	control and developmental sites	For life of project
55.	C. Vegetation Herb Production (current live)	increased grazing	reduced standing live	30% slope in annual trend line.	.erb utilization	herb utilization-clip annually at all sites available to grazing	control and developmental sites	
		air pollutants	reduced standing live					
		introduction of toxic elements	reducing standing live			Bioassay		Following mine dewatering & retort emissions
		elimination and degradation of habitat	reduced standing live for Tract as a unit					All during construction
56.	Shrub production (biomass)	increased browsing (this could be due to habitat elimination reducing the carrying capacity while deer numbers remain constant)	reduced production, therefore reduced carrying capacity	30% slope in annual trend line.	deer population numbers on Tract	attain sampling adequacy	control and developmental sites	One year after construction until a period following construction
		air pollutants and toxic elements	reduced production, therefore reduced carrying capacity	professional judgement		Bioassay	control and developmental sites	Sometime after mine dewatering and retort emissions
		elimination and degradation of habitat	reduced production, therefore reduced carrying capacity for Tract as a unit	will be recorded on the Tract record				Throughout construction
57.	Herb utilization (will be treated as a secondary variable to herb production and composition)	increased grazing	reduced herb production, and a possible shift in species composition	30% slope in annual trend line.	AUM's Check with ranchers	Annual herb utilization clip at all sites open to grazing	control and developmental sites	
58.	Shrub utilization (biomass)	increased browsing (altered utilization of Tract could give spurious results of comparisons between control and treatments)	reduced shrub production, reducing available browse for utilization	30% slope in annual trend line.	Deer population numbers on Tract	attain sampling adequacy	control and developmental sites	After construction begins and habitats used for browse are lost
59.	General Condition (CIR)	air pollutants, water stress, and insect damage	productivity reduced, species composition change.	professional judgment	Air quality data, meteorology data, and field inspections.	Bioassay	control and developmental sites	For life of project
60	MicroClimate Study	NONE	information will be used as variables for shrub and herb productivity and utilization.	NONE	NONE	NONE	NONE	NONE
61.	Community composition (frequency, density, & cover)	increased browsing and grazing	herbs - reduced litter which leads to reduced moisture retention, and could favor certain species thus shifting the species composition selective grazing - some species favored over others by cattle, thus creating a change in species composition.	30% slope in annual trend line.	Herb utilization Shrub utilization	Attain sampling adequacy	Control and developmental sites	At anytime during the life of the project.
		excessive irrigation	a shift in the community representing a more mesic environment	30% slope in annual trend line.	Amount of water applied Amount of precipitation applied			Following irrigation
62.	Acreage (record of disturbed, undisturbed, re-established)		elimination & degradation of habitats		Aerial flights			Life of project

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NEWMAN KEULS MULTIPLE COMPARISON TEST

The Newman-Keuls multiple comparison test is generally used after an analysis of variance has first rejected a multisample hypothesis of equal means. Newman-Keuls considers the null hypothesis H_0: $\mu_A = \mu_B$ versus the alternative hypothesis H_A: $\mu_A \neq \mu_B$ where the subscripts denote any possible pair of groups.

Example:

The data are measurements of herbaceous productivity in kg/hectare in three tract vegetation types.

First an analysis of variance is performed:

H_0: $\mu_A - \mu_B = \mu_C$

H_A: Productivity amounts are not equal in the vegetation types

$\alpha = 0.05$, 1-tailed test

VEG TYPE 1	VEG TYPE 2	VEG TYPE 3
28.2	39.6	41.0
33.2	40.8	44.1
36.4	37.9	46.4
34.6	37.1	40.2
$\bar{x}_1$=33.1kg/h	$\bar{x}_2$ =38.9kg/h	$\bar{x}_3$=42.9kg/h
n_1=4	n_2=4	n_3=4

Source of Variation	SS	DF	MS
Total	341.51	11	31.05
Group	271.43	2	135.72
Error	70.08	9	7.79

$$F = \frac{135.72}{7.79} = 17.42$$

Since $F_{0.05(1),2,9} = 4.26$, H_0 cannot be accepted.

Since a significant F resulted from the analysis of variance, the Newman-Keuls multiple range test may now be applied.

Newman-Keuls Example (Continued)

Ranks of sample means (i)	1	2	3
Ranked sample means ($\bar{x}_i$ in kg/h)	33.1	38.9	42.9

To test each H_0: $\mu_B = \mu_A$ at $\alpha=0.05$

$$SE = \sqrt{\frac{7.79}{4}} = \sqrt{1.9475} = 1.3955 \cong 1.40$$

Comparison B vs. A	Difference ($\bar{x}_B - \bar{x}_A$)	SE	q*	p	$q_{0.05,q,p}$	Conclusion
3 vs. 1	42.9 - 33.1 = 9.8	1.40	7.0	3	3.949	Reject H_0: $\mu_3=\mu_1$
3 vs. 2	42.9 - 38.9 = 4.0	1.40	2.87	2	3.199	Accept H_0: $\mu_3=\mu_2$
2 vs. 1	38.9 - 33.1 = 5.8	1.40	4.14	2	3.199	Reject H_0: $\mu_2=\mu_1$

Overall Conclusion: $\mu_1 \neq \mu_2 = \mu_3$

We conclude that samples 2 and 3 came from the same population but sample 1 came from a different population.

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* The studentized ranges ($q = \frac{\bar{x}_B - \bar{x}_A}{SE}$) are compared with the critical values of q as listed in Biological Statistics, Zar.

REGRESSION AND CORRELATION ANALYSIS

A discussion of the regression and correlation analysis methods previously used with Tract C-b data and expected to be of continued use in the analysis of this data follows as it appeared in Appendix A of the Final Environmental Baseline Report for Tract C-b.

A.2.2 Statistical Analysis Methods

A.2.2.1 Analysis of Variance

Analysis of variance in a factorial design of an experiment is used in assessing the effects of changing controlled levels of two or more variables. Analysis of variance is especially useful if the number of variables is between 3 and 10, and when the controlled levels for each variable are between 2 and 6.

The parameters used in this study are not controlled, but are identified and measured as a result of selective sampling. The parameters are ammenable to grouping so that the data has been ordered into matrices similar to those used in factorial design. Analysis of variance applied to the matrices can assess the contribution of each parameter to the sum of square of the deviations from the mean. Interactions between parameters identified in this analysis must be interpreted carefully since this is not a controlled experimental design.

Table A-2-1 shows how shrub importance values have been regrouped by soil type and plant community to produce a matrix of four classification parameters. The parameters included are eight species of shrubs, three sample sites, three vegetation and soil types, and two sets of data. The two sets of data are, at best, only similar.

A.2.2.2 Regression and Correlation Analysis

Correlation considers the joint variation of two measurements, neither of which is controlled by the investigator. Regression considers the frequency distributions of one variable when another is held constant at each of several levels. Treating one of several variables as a dependent permits the calculation of a mathematical relationship between the dependent variable and the several independent variables. A statistical test of independence based on the coefficients of regression and standard errors of the estimates can be used to identify significant relationships between the individual parameters.

Multiple linear regression analysis has been applied to the data in this study in order to assess the significance of relationships and correlations between various shrub and herbaceous species. Relationships between species as well as the relationship between vegetation and soil constituents has been treated using multiple regression procedures.

In these analyses, simple and partial coefficients of correlation have been developed between pairs of data observations. Simple correlation shows the relationship between two variables and reflects the effects of the other variables. Partial correlation demonstrates the correlation between two variables, while discounting or holding constant the effects of the other variables. Multiple correlations have been developed between a dependent variable and several other

Table A-2-1 CLASSIFICATION OF VARIABLES FOR ANALYSIS OF VARIANCE

SHRUB IMPORTANCE VALUES

SOILS VERSUS SHRUB IMPORTANCE VALUES

SAMPLE	SOIL	TYPE	OPPO A1	ARTR A2	SYOR A3	JUOS A4	PUTR A5	PIED A6	AMSP A7	CHNA A8			
4-4	(41)404F	BLSB	12.6	245.4	0.0	0.0	2.7	0.0	0.0	7.5	B1	C1	D1
A16	(41)16	BLSB	16.4	225.6	8.2	0.0	0.0	0.0	0.0	49.8	B2		
A19	(41)19	BLSB	7.6	261.8	0.0	0.0	0.0	0.0	0.0	30.0	B3		
5-5	(63)505F	PJWD	0.0	86.9	0.0	14.2	24.3	65.6	65.6	5.6	B1	C2	
A9	(63)9	PJWD	19.4	49.8	5.8	14.8	145.6	41.8	0.0	0.0	B2		
A13	(63)13	PJWD	0.0	14.9	113.9	4.1	23.5	11.0	34.2	4.9	B3		
2-2	(66)202F	CPJR	11.9	34.3	10.2	34.4	38.6	50.0	14.9	64.8	B1	C3	
A7	(66)7	CPJR	17.5	78.5	104.2	23.3	11.0	12.6	18.5	5.9	B2		
A10	(66)10	CPJR	6.2	124.5	9.9	16.6	86.5	28.9	9.9	9.0	B3		
3-3	(71C)303F	UPSB	23.8	234.2	0.0	2.8	0.0	16.0	16.8	5.0	B1	C1	D2
A15	(71C)15	UPSB	2.6	133.8	41.6	0.0	1.2	7.7	49.2	58.8	B2		
A11	(70)11	UPSB	24.9	235.9	2.2	7.1	0.0	21.5	2.6	0.0	B3		
1-1	(63)101F	CPJR	6.8	141.7	10.1	13.3	32.3	19.5	11.3	26.5	B1	C2	
A20	(63)20	BUGR	4.7	31.7	0.0	0.0	0.0	0.0	0.0	3.4	B2		
A21	(63)21	DGFF	0.0	0.0	106.1	16.0	0.0	11.8	0.0	0.0	B3		
6-6	(66)606F	PJWD	45.8	171.0	3.0	16.7	2.5	23.5	25.4	26.7	B1	C3	
A14	(66)14	CPJR	1.6	3.2	100.9	29.2	17.9	38.3	31.3	1.6	B2		
A12	(66)12	PJWD	28.3	113.1	14.2	7.5	5.7	49.6	35.0	0.0	B3		

independent variables. The multiple regression equation is a mathematical expression stating the statistical dependence of one variable on several independent variables as in the following equation:

(Eq. No. 2-1)

$$\bar{y}_x = b_o + b_1 x_1 + b_3 x_3 + \ldots\ldots + b_n x_n$$

where: $\bar{y}_x$ = the estimate of y based on observations of a set of x variables which may influence y

b_o = the intercept or value of y when values of all x are zero

b_1, b_2 = are the regression coefficients for all corresponding x variables

x_1, x_2 = the independent variables observed

n = the number of independent variables observed

The regression equation is determined by multiple linear regression analysis and evaluating many sets of observations of a dependent variable and corresponding independent variables. The analysis determines the intercept (b_o) and the regression coefficients (b_i). The equation is used to calculate estimated values of the dependent variable ($\bar{y}_x$). Residual values exist as the differences between the estimated values ($\bar{y}_x$) and the observed value of the dependent variable. Multiple linear regression analysis determines the set of regression coefficients (b_i and b_o) that minimizes the sum of the residuals.

Correlation and regression analyses were performed using an IBM 370/168 computer and a multiple linear regression program. Analyses performed correlated shrub species with shrub species, herb species with herb species, soil characteristics with soil characteristics, and each of the vegetation species with each soil characteristic. A typical computer output is shown in Appendix B, Table B-2-9.

In this analysis juniper (Juniperus osteosperma JUOS) (dependent variable) is correlated with a set of soil characteristics (independent variable). The simple correlation coefficients, regression coefficients, and computed T-values are the principal statistics discussed in the following analysis.

Shrub correlations are shown in Appendix IV-B, Table B-2-6. Values shown are segregated to indicate three levels of statistical significance: confidence intervals at 95, 90, and 75 percent (the smaller the percent, the larger the interval). These segregations were employed to introduce the opportunity for assessing correlations on a more complete biological level rather than on the basis of statistics alone.

TABLE B-1-10

ANALYSIS OF VARIANCE

UPLAND SAGEBRUSH, BOTTOMLAND SAGEBRUSH, AND PINYON-JUNIPER WOODLAND

LEVELS OF FACTORS

A	5	Parameters (Temperature: Ambient, Surface, Soil at -20 cm & -60 cm and Precip.)
B	13)	65 observation by date
C	5)	
D	3	stations

GRAND MEAN 3.20477

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES
A	3086.37451	4	771.59351
B	1361.46167	12	113.45514
AB	573.64331	48	11.95090
C	16001.9062	4	4000.47656
AC	4844.58203	16	302.78638
BC	12705.0273	48	264.68799
ABC	4906.42187	192	25.55428
D	616.37183	2	308.18579
AD	240.60751	8	30.07593
BD	403.76465	24	16.82352
ABD	387.10742	96	4.03237
CD	460.78394	8	57.59799
ACD	308.07520	32	9.62735
BCD	703.65259	96	7.32971
ABCD	1111.28052	384	2.89396
TOTAL	47711.0430	974	

Table B-1-12 ANALYSIS OF VARIANCE
MONTHLY PRECIPITATION

Means for the Four Major Vegetation Types	
Chained Pinyon-Juniper Rangeland	- 18.9 mm
Pinyon-Juniper Woodland	- 20.7 mm
Upland Sagebrush	- 20.9 mm
Bottomland Sagebrush	- 19.3 mm

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares
Total	736979.3	87	
Groups	66.8	3	22.3
Error	736912.5	84	8772.8

Table B-2-3 HERB FREQUENCY VALUES

VEGETATION STAND NO.[2]	VEGETATION TYPE	SPECIES[1] AGSM	FEBR	KOGR	ORHY	CAPE	SPCO	STCO	BRTE	PILO
4F & 4-0	BLSB	50	0	0	26	0	0	8	100	0
19	BLSB	10	0	0	45	0	.5	0	100	0
16	BLSB	70	75	100	0	0	25	80	100	0
19	BLSB	10	0	0	45	0	5	0	100	0
1F & 1-0	CPJR	20	8	18	56	24	0	18	81	8
5F & 5-0	PJWD	16	4	0	58	30	0	4	30	0
9	PJWD	80	0	30	45	40	0	20	10	0
9	PJWD	80	0	30	45	40	0	20	10	0
13	PJWD	60	0	45	35	0	5	50	10	0
20	BUGR	10	0	0	90	0	0	0	35	0
21	DGFF	0	60	30	0	40	0	0	0	0
2F & 2-0	CPJR	26	4	10	14	4	6	4	98	8
6F & 6-0	PJWD	74	52	44	8	34	20	34	16	66
F	CPJR	85	45	55	50	40	0	50	20	0
14	CPJR	55	45	50	55	15	20	0	55	0
7	CPJR	85	45	55	50	40	0	50	20	0
8	UPSB	80	15	90	30	35	15	25	10	0
10	CPJR	55	0	40	40	0	5	50	0	0
12	PJWD	80	85	65	0	55	20	70	25	0
14	CPJR	55	45	50	55	15	20	0	55	0
11	UPSB	100	502	100	75	50	95	30	0	0
11	UPSB	100	25	100	75	50	95	30	0	0
3F & 3-0	UPSB	100	74	100	0	88	52	22	4	98
15	UPSB	100	75	100	0	45	40	65	0	0
18	GRWD	55	0	0	0	0	0	0	75	0
18	GRWD	55	0	0	0	0	0	0	75	0

[1]See Table 3-2-14 (Chapter 3, Section 2) for explanation of abbreviations.
[2]See Table B-2-5 (Appendix B, Section 2) for explanation of numbers.

Table B-2-9 TYPICAL COMPUTER OUTPUT FOR CORRELATION AND REGRESSION ANALYSIS

MULTIPLE REGRESSION.....,VAL1
SELECTION ... 4

:01262201020304050607080910111213141516171819202122

VARIABLE NO. NAME	MEAN	STANDARD DEVIATION	CORRELATION X VS Y	REGRESSION COEFFICIENT	STD. ERROR OF REG.COEF.	COMPUTED T VALUE
1 NO_3	9.55000	5.79904	-0.13283	-0.00000	0.00011	-0.00937
2 NH4	0.90500	0.60304	0.03848	-0.00070	0.02327	-0.03015
3 P	8.35000	7.58998	0.44656	0.00001	0.00025	0.04392
4 K	145.64999	83.20306	-0.40796	-0.00000	0.00002	-0.07368
5 Ca	4340.00000	1020.01001	0.39899	0.00000	0.00001	0.08447
6 Mg	339.00000	148.21391	0.25149	0.00006	0.00072	0.08442
7 SO4	21.84999	9.85299	-0.27306	-0.00154	0.08034	-0.01902
8 Fe	5.73000	5.99114	0.26168	0.00000	0.00030	0.01300
9 Zn	0.42500	0.76769	0.23964	-0.00194	0.05754	-0.03379
10 Cu	0.42500	0.25726	0.09307	0.00045	0.00169	0.26883
11 Mn	2.04000	1.92146	0.19412	-0.00001	0.00033	-0.02118
12 B	0.60000	0.12978	-0.18213	0.00341	0.13187	0.04100
13 CEC	30.48494	5.85349	0.43800	0.00000	0.00002	0.01252
14 pH	8.19999	0.29380	-0.32419	-0.00071	0.00529	-0.13469
15 %LIM	5.27999	2.70858	0.07730	-0.00002	0.00070	-0.03426
16 SALT	0.72000	0.31221	-0.15467	0.01226	0.00430	2.85143
17 ESP	2.10499	1.58229	-0.44963	-0.00337	0.01999	-0.16850
18 PWC	16.16498	5.24918	0.37351	-0.00131	0.01436	-0.09090
19 FC	23.89996	6.22363	0.42815	0.18516	0.27984	0.66168
20 %AW	7.73500	3.55709	0.19791	-0.14037	0.69846	-0.20126
21 %OM	3.16000	1.17267	0.42770	1.68024	3.33131	0.50438
22 OMN	116.20000	36.66718	0.33068	-0.02540	0.12703	-0.19997
DEPENDENT						
26 JUOS	3.54500	3.00604				

INTERCEPT -2.11943

MULTIPLE CORRELATION 0.55769

STD. ERROR OF ESTIMATE 6.27936

ANALYSIS OF VARIANCE FOR THE REGRESSION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F VALUE
ATTRIBUTABLE TO REGRESSION	22	53.39835	2.42720	-0.06156
DEVIATION FROM REGRESSION	-3	118.29099	-39.43033	
TOTAL	19	171.68933		

MULTIPLE REGRESSION.....,VAL1
SELECTION 4

TABLE OF RESIDUALS

CASE NO.	Y VALUE	Y ESTIMATE	RESIDUAL
1	0.00000	2.42178	-2.42178
2	0.00000	4.66675	-4.66675
3	0.00000	1.25160	-1.25160
4	0.00000	0.26412	-0.26412
5	3.30000	2.28360	1.01640
6	6.00000	4.98825	1.01175
7	4.20000	4.71901	-0.51901
8	4.80000	3.34391	1.45609
9	4.10000	2.83138	1.26862
10	4.40000	2.39278	2.00722
11	3.30000	3.22357	0.07643
12	6.60000	6.59855	0.00145
13	9.20000	4.54732	4.65268
14	6.70000	6.75922	-0.05922
15	7.50000	3.01560	4.48440
16	0.90000	3.81360	-2.91360
17	7.10000	4.41748	2.68252
18	2.80000	3.76557	-0.96557
19	0.00000	4.31573	-4.31573
20	0.00000	1.28051	-1.28051

SHANNON-WEINER SPECIES DIVERSITY INDICES

Shannon's index of diversity is a quantitative expression of diversity in nominal scale data. The indices of diversity have no associated null hypothesis, H_0. However, they may be used at a later date in testing the null hypothesis,

> H_0: No significant difference exists in species composition between developmental and control sites now or over time.

The appropriate test of this hypothesis would be Hutcheson's T-Test.

In the following example, Shannon's calculation has been used to compute indices of small mammal species diversity (H') and relative diversity (J) for the habitat type sampled. Additional indices-statistics might be observed in a table similar to Table B-4-8 of the Final Environmental Baseline Report for Tract C-b.

Example

Indices of Diversity for Nominal Scale Data. The feeding ground of small mammals.

Category (i)	Observed Frequencies (f_i) in Transect No. 1	
Species found in Ag Meadow Transect 1	Sample 1*	Sample 2*
Species No. 1	10	12
Species No. 2	5	7
Species No. 3	3	3
Species No. 4	5	5
Species No. 5	2	2
Species No. 6	5	7
Species No. 7	0	2
Species No. 8	1	4
Species No. 9	1	1
Species No. 10	2	1
	n= 34	n= 44

$$H' = \frac{n \log n - \sum_{i=1}^{k} f_i \log f_i}{n} \qquad J = \frac{H}{H'_{max}}$$

H'_{max} = log k

k = No. of species

n = Total observed frequenc

Sample 1. $H' = (34 \log 34 - (10 \log 10 + 5 \log 5 + 3 \log 3 + 5 \log 5 + 2 \log 2 + 5 \log 5 + 1 \log 1 + 1 \log 1 + 2 \log 2)) \div 34$

$= (52.070 - (10.000 + 3.495 + 1.431 + 3.495 + 0.6021 + 3.495 + 0 + 0 + 0.6021)) \div 34$

$= 28.9500 \div 34 = \underline{0.8515 = H'}$

$H'_{max} = \log 9 = 0.954$ $J = 0.8515 \div 0.954 = \underline{0.893 = J}$ (Relative Diversity)

Sample 2. $H' = (44 \log 44 - (12 \log 12 + 7 \log 7 + 3 \log 3 + 5 \log 5 + 2 \log 2 + 7 \log 7 + 2 \log 2 + 4 \log 4 + 1 \log 1 + 1 \log 1)) \div 44$

$= 72.312 - (12.950 + 5.916 + 1.431 + 3.495 + 0.602 + 5.916 + 0.602 + 2.408 + 0 + 0) \div 44$

$= 38.992 \div 44 = \underline{0.886 = H'}$

$H'_{max} = \log 10 = 1.000$ $J = 0.886 \div 1 = \underline{0.886} = \underline{J}$ (Relative Diversit

* Sample 1 taken in Spring for 3 consecutive nights.
Sample 2 taken in Fall for 3 consecutive nights.
Each transect contains 25 traps per night.

Table B-4-8

SHANNON-WEINER DIVERSITY INDICES (H'), UNBIASED ESTIMATES OF H' (E(H')), VARIANCE OF H' (VAR(H')), MAXIMUM EXPECTED VALUE OF H' (H' (MAX)), AND EQUITABILITY (J) FOR ALL AVIFAUNA TRANSECTS, 1974-1976

Sampling Date	Transect	Vegetation Type	H'	E(H')	var(H')	H'(max)	J
October 1974	1	Chained pinyon-juniper rangeland	1.116	1.071	0.015	1.386	0.805
	2	Riparian meadow	1.464	1.441	0.003	2.303	0.636
	3	Bottomland sagebrush	1.426	1.385	0.010	1.946	0.733
	4	Pinyon-juniper woodland	1.277	1.221	0.009	1.386	0.921
	5A	Pinyon-juniper woodland	0.673	0.559	0.028	0.693	0.971
	6	Canyon sagebrush	0.000	0.000	0.000	0.000	-
	7A	Upland sagebrush	-	-	-	-	-
	8	Mixed mountain shrub	1.034	1.014	0.003	1.099	0.941
November 1974	1	Chained pinyon-juniper rangeland	0.693	0.339	0.125	0.693	1.000
	2	Riparian meadow	1.320	1.311	0.001	1.609	0.820
	3	Bottomland sagebrush	0.637	0.417	0.091	0.693	0.918
	4	Pinyon-juniper woodland	0.686	0.634	0.006	0.693	0.990
	5A	Pinyon-juniper woodland	-	-	-	-	-
	6	Canyon sagebrush	-	-	-	-	-
	7A	Upland sagebrush	-	-	-	-	-
	8	Mixed mountain shrub	-	-	-	-	-

HUTCHESON'S T-TEST

Hutcheson's T-Test may be used to test the null hypothesis that the diversities of two sampled populations are equal.

$$t = \frac{H'_1 - H'_2}{S_{H'_1 - H'_2}}, \text{ where } S_{H'_1 - H'_2} = \sqrt{S^2_{H'_1} + S^2_{H'_2}}$$

$$H' = \frac{n \log n - \Sigma f_i \log f_i}{n}$$

$$S^2_{H'} = \frac{\Sigma f_i \log^2 f_i - (\Sigma f_i \log f_i)^2/n}{n^2}$$

logarithms to any base may be used - those to base 10 are most common.

$$\nu = \frac{(S^2_{H'_1} + S^2_{H'_2})^2}{\frac{(S^2_{H'_1})^2}{n_1} + \frac{(S^2_{H'_2})^2}{n_2}}$$

$$f_i \log^2 f_i = \frac{(f_i \log f_i)^2}{f_i}$$

A one or two-tailed hypothesis may be used.

Notice that $(\Sigma f_i \log f_i)$ is calculated in H'.

In the following example, Hutcheson's T-Test tests the equality of Spring and Fall small mammal diversity indices for a Transect at Tract C-b. The actual calculations of these indices are illustrated as an example of the Shannon-Weiner species diversity indices.

Example

Testing a null hypothesis using Hutcheson's T-Test:

H_0: The diversity of small mammal species trapped in the Spring at Transect No. 1 is the same as the diversity of small mammal species trapped in the Fall at Transect No. 1.

Sample No. 1 (Spring Sample)

Species	Frequency (f_i)	$f_i \log f_i$	$f_i \log^2 f_i$
1	10	10.000	10.000
2	5	3.495	2.443
3	3	1.431	0.683
4	5	3.495	2.443
5	2	0.602	0.181
6	5	3.495	2.443
7	0		
8	1	0	0
9	1	0	0
10	2	0.602	0.181

$S_1=9$ $n_1=\Sigma f_i=34$ $\Sigma f_i \log f_i = 23.120$ $\Sigma f_i \log^2 f_i = 17.374$

Sample No. 2 (Fall Sample)

Species	Frequency (f_i)	$f_i \log f_i$	$f_i \log^2 f_i$
1	12	12.950	13.975
2	7	5.916	5.000
3	3	1.431	0.683
4	5	3.495	2.443
5	2	0.602	0.181
6	7	5.916	5.000
7	2	0.602	0.181
8	4	2.408	1.450
9	1	0	0
10	1	0	0

$S_2=10$ $n_2=\Sigma f_i=44$ $\Sigma f_i \log f_i = 33.320$ $\Sigma f_i \log^2 f_i = 28.913$

Example Cont'd

$H'_1 = 0.8515$

$S^2_{H'_1} = \frac{17.374 - 15.722}{1156} = 0.00142907$

$H'_2 = 0.886$

$S^2_{H'_2} = \frac{28.913 - 25.232}{1936} = 0.00190134$

$S_{H'_1 - H'_2} = \sqrt{S^2_{H'_1} + S^2_{H'_2}} = \sqrt{0.00333041} = 0.05770973$

$t = \frac{H'_1 - H'_2}{S_{H'_1 - H'_2}} = \frac{0.8515 - 0.8860}{0.05770973} = -0.59781946$

$$\nu = \frac{(S^2_{H'_1} + S^2_{H'_2})^2}{\frac{(S^2_{H'_1})^2}{n_1} + \frac{(S^2_{H'_2})^2}{n_2}} = \frac{(0.00142907 + 0.00190134)^2}{\frac{(0.00142907)^2}{34} + \frac{(0.00190134)^2}{44}} = \frac{0.000011092}{0.000000142} = 78.02 \cong 78$$

$\alpha = 0.05$, 2 tailed test

$t_{.05(2),\ 78} = 1.991$

Therefore do not reject H_0.

Univariate Time Series

Time series analysis based on the Box Jenkins Technique ((Box and Jenkins (1976) and Nelson (1973)) is utilized to capture all of the statistically significant information contained in the series for the purpose of forecasting future trends and values for the series. Techniques are developed and programmed in computer models for both single (univariate) and multiple time series (transfer function). This example presents only the univariate time series case.

The United Computer Service (UCS) computer program identified as FORTELL was utilized in this example. It is an interactive model with two levels of prompting. The more detailed option is illustrated in this example.

The example presented is for water temperature data collected over a thirty-nine (39) month period at USGS Station 07 on Piceance Creek.

DESCRIPTION OF INPUTS & OUTPUTS FOR TEMPS 07

Introduction to I.D. Process

The identification section for a time series analysis provides the user with a quantitative measure of the amount of statistical information contained within the data series. This is accomplished through the use of the autocorrelation and partial autocorrelation functions. These functions, as well as some other statistically relevant information, allow the user to choose the initial form of the time series model.

Identification for Temp 07

The following discussion is concerned with temperature data measured in degrees centigrade and temperature data collected at station 07 for the period starting 10/74 and ending 12/77. Additionally, the computer output was generated by the United Computer System's library program, FORTELL. For details of the following descriptions refer to the appropriate computer printout and associated graphs. Examination of the autocorrelation data indicates that:

1) The Temp 07 series is stationary, i.e., the autocorrelations die out rapidly.

2) The model for the time series is likely to contain autoregressive parameters. This is revealed by the appearance of an exponential decay in the autocorrelation function.

Due to the autoregressive nature of the series, examination of the partial autocorrelation function indicates the number and location of these autoregressive parameters. There are significant spikes at lags of 1, 2, and 4, therefore an initial estimation and diagnostic check is made using this autoregressive model with three parameters at lags 1, 2, and 4.

Estimation for Temp 07

The estimation process does not indicate that the lag 2 parameter is significant; it is therefore dropped from the model. Another estimation is done using this more parsimonious model, and it is seen that the remaining two parameters are significant.

Diagnostic Check for Temp 07

In order to evaluate the developed autoregressive model an analysis is performed on the series residuals. If the present model is correct, that is to say, there is no remaining statistical information available from the data, then the residuals will have been reduced to white noise. An inspection of the autocorrelations of the residuals shows no significant values, hence it may be assumed that the present model cannot be rejected.

One Step Ahead Forecasts for Temp 07

The one step ahead forecasting process is yet another method to evaluate the adequacy of the model. These forecasts are based upon the model and the past data and are made for only one period into the future. This yields values which are unbiased and uncorrelated; one is then able to generate a forecast series which

can then be compared to the actual series employing a known confidence limit. If the model is correctly describing the data, the forecasted series will be contained within the confidence limit at the appropriate level. As can be seen, the autoregressive model that has been developed does satisfy this requirement.

<u>Adaptive Forecasts for Temp 07</u>

The adaptive forecasting process is the result one finally desires to reach. This process starts at the end of the time series and yields optimal forecasts of the future. It should be noted that the adjective, adaptive, is included in the description because the forecast has the ability to adapt itself to the most recent changes in the series.

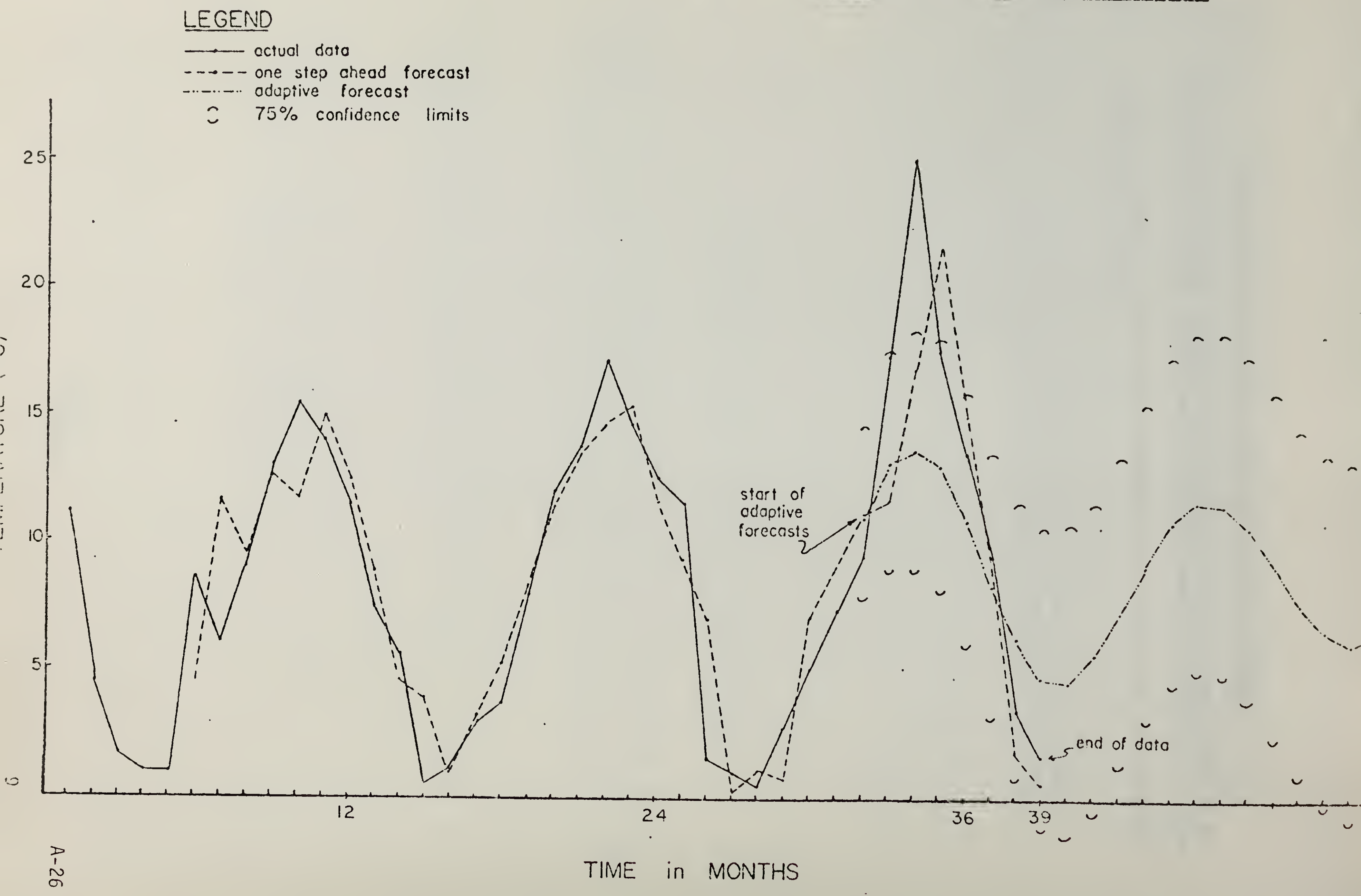
GRAPHIC REPRESENTATION FOR TEMPS 07 & COMPUTER OUTPUT

The following two time series plots are for TEMP 07, they are for the same model, i.e., AR(4), but show different time origins for the forecasts.

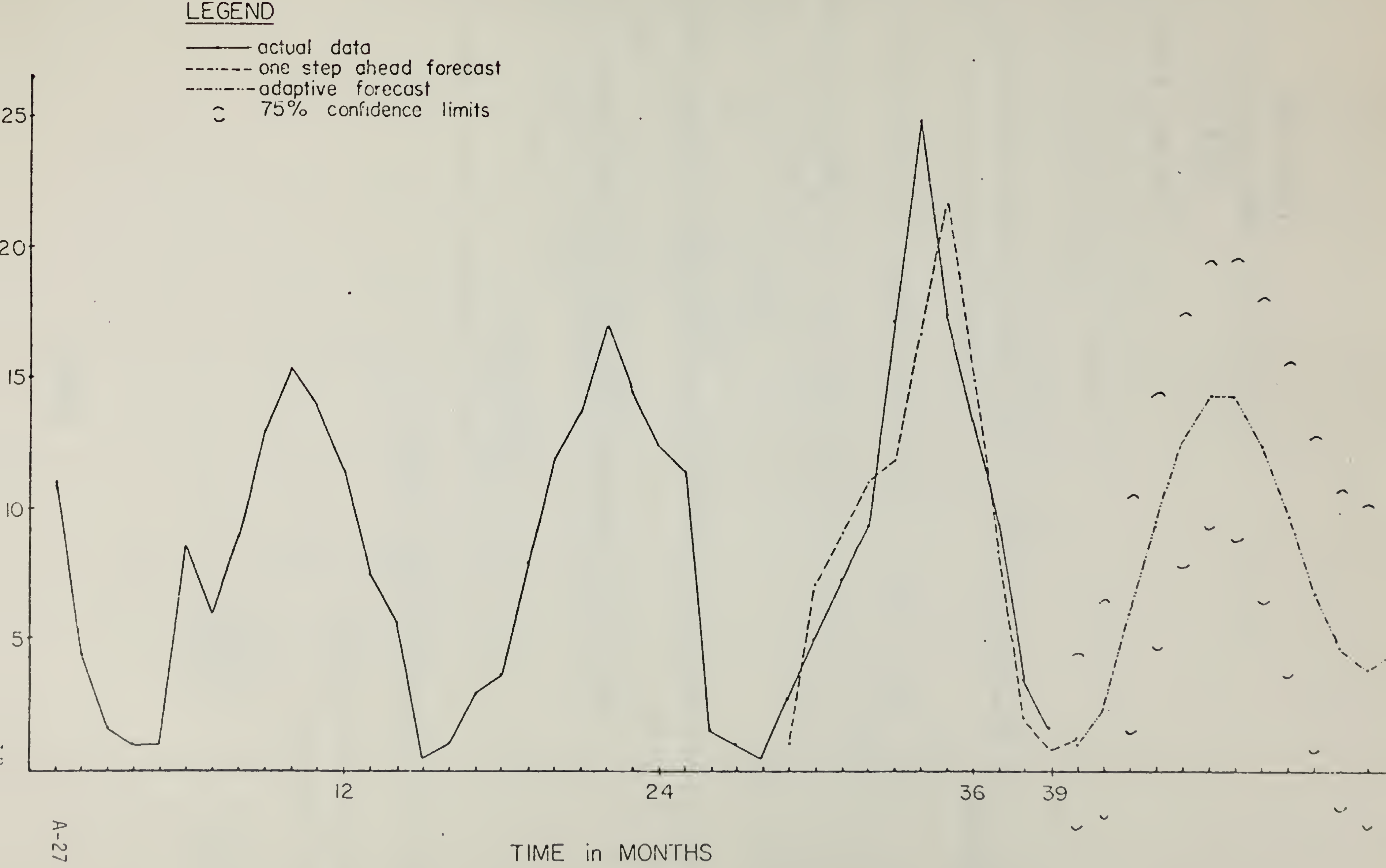
Following the two graphs is the computer output from the FORTELL program.

TEMPERATURE at USGS STATION 07 vs TIME

FORECAST MODEL: AR (4)



FORECAST MODEL : AR (4)



TEMP Ø7
AR $_{1,2,3,4,\theta_0}$
UCS
I.D. AND E.D.F.

```
[illegible]

[illegible] 04/13/78, 10.37.43, 3073
USER [illegible]UCS113C
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
00100 11.2 4.3 1.7
00110 1.0 1.0 8.7 6.0 9.0 13.1 15.5 14.0 11.5 7.5 5.7 0.5
00120 1.0 3.0 3.8 8.0 12.0 13.2 17.1 14.7 12.5 11.5 1.5 1.0
00130 0.9 2.8 5.0 7.3 9.5 17.3 25.0 17.5 13.5 9.5 3.5 1.7
[illegible]
[illegible]ELL/LIB

*****************************************************************************************

DATE  04/13/78.                                                          TIME  10.40.(

            BOX-JENKINS UNIVARIATE TIME SERIES ANALYSIS PACKAGE
            ---------------------------------------------------

                                  DATA MODULE
                                  -----------

ENTER TIME SERIES FILE NAME ? OXYDATA

ORIGINAL SERIES OXYDATA

DATA POINTS= 39

MEAN        =     8.30000
VARIANCE    =     36.6905
MINIMUM     =     .500000
MAXIMUM     =     25.0000
```

```
ER DATA MODULE OPTION DESIRED,'HELP' OR (  1 -  5) ? HELP

TA MODULE OPTIONS:

    1) DATA INPUT
    2) DATA PREPARATION AND DISPLAY
    3) DATA TRANSFORMATION
    4) CONTINUE TO IDENTIFICATION MODULE
    5) RETURN TO CONTROL MODULE

TER DATA MODULE OPTION DESIRED,'HELP' OR (  1 -  5) ? 2

OTE: WORKING WITH UNTRANSFORMED SERIES

TER DATA PREPARATION OPTION DESIRED,'HELP' OR (  1 - 13) ? HELP

ATA PREPARATION OPTIONS:

    1) PLOT TIME SERIES
    2) INSERT VALUES IN TIME SERIES
    3) CHANGE VALUES IN TIME SERIES
    4) REMOVE VALUES FROM TIME SERIES
    5) COMBINE VALUES IN TIME SERIES
    6) MULTIPLY SERIES BY CONSTANT
    7) DIVIDE SERIES BY CONSTANT
    8) ADD SECOND SERIES TO SERIES
    9) SUBTRACT SECOND SERIES FROM SERIES
   10) MULTIPLY SERIES BY SECOND SERIES
   11) DIVIDE SERIES BY SECOND SERIES
   12) SAVE PREPARED TIME SERIES
   13) EXIT DATA PREPARATION

TER DATA PREPARATION OPTION DESIRED,'HELP' OR (  1 - 13) ? 1
```

PLOT A TIME SERIES (Y/N) ? Y

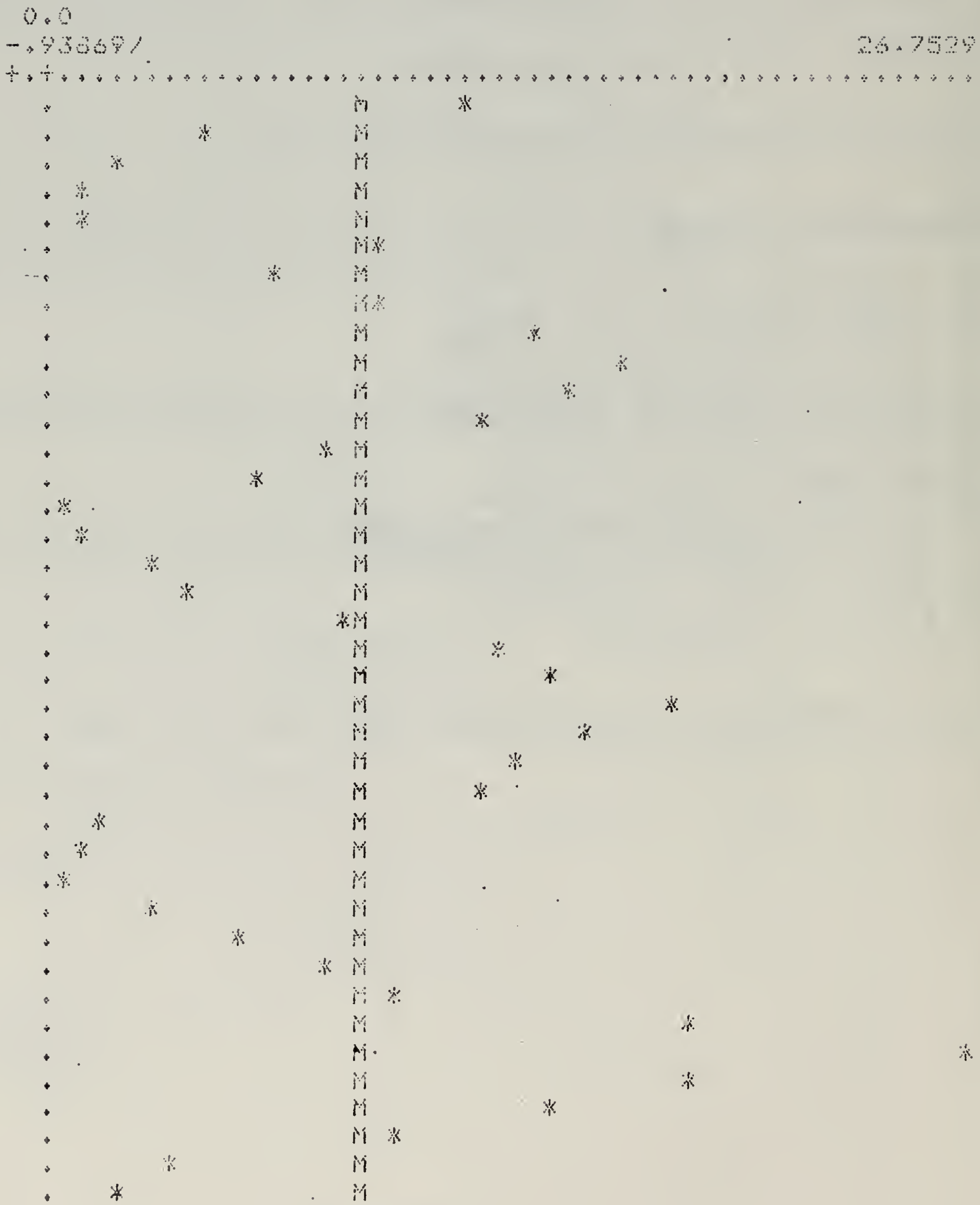
SERIES OXYDATA

SERIES NOT DIFFERENCED

DATA POINTS = 39

MEAN = 8.30000 VARIANCE = [illegible]
MINIMUM = .500000 MAXIMUM = 25.0000

GRAPH INTERVAL = .469349
M - MEAN VALUE



DATA POINT	VALUE
1	11.2000
2	4.30000
3	1.70000
4	1.00000
5	1.00000
6	8.70000
7	6.00000
8	9.00000
9	13.1000
10	15.5000
11	14.0000
12	11.5000
13	7.50000
14	5.70000
15	.500000
16	1.00000
17	3.00000
18	3.80000
19	8.00000
20	12.0000
21	13.8000
22	17.1000
23	14.7000
24	12.5000
25	11.5000
26	1.50000
27	1.00000
28	.500000
29	2.80000
30	5.00000
31	7.50000
32	9.50000
33	17.5000
34	25.0000
35	17.5000
36	13.5000
37	9.50000
38	3.50000
39	1.70000

```
.A  ATA PREPARATION OPTION DESIRED,'HELP' OR (  1 - 13) ? 13

    SERIES 0:YDATA

      NT(= 3)

          =      4.30000
IANCE     =      36.8905
          =      .500000
    1     =      23.0000

ER DATA MODULE OPTION DESIRED,'HELP' OR (  1 -  5) ? 4

************************************************************************************************

UM CPU SECONDS        .11
UM CONNECT HOURS      .12
```

IDENTIFICATION MODULE

```
T SERIES (Y/N) ? N

ER NO. OF LAGS FOR AUTOCORRELATION FUNCTION (ACF) (  0 - 38) ? 24
```

S	1	2	3	4	5	6	7	8
UE	.753	.385	-.016	-.404	-.628	-.687	-.590	-.331
STD ERR	.320	.468	.499	.499	.532	.603	.679	.729
S	9	10	11	12	13	14	15	16
UE	.006	.314	.542	.594	.487	.245	-.008	-.245
STD ERR	.745	.745	.758	.797	.841	.869	.876	.877
S	17	18	19	20	21	22	23	24
UE	-.410	-.448	-.365	-.215	-.007	.171	.309	.342
STD ERR	.883	.903	.925	.940	.945	.945	.948	.958

```
-SQUARE STATISTIC =  159.672      WITH  23 DEGREES OF FREEDOM

OT AUTOCORRELATION FUNCTION (ACF) (Y/N) ? Y
```

AUTOCORRELATION FUNCTION OF SERIES [illegible]

SERIES NOT DIFFERENCED

```
                -1.0     -.67      -.33      0.0       .33       .67
LAG      VALUE  +.........+.........+.........+.........+.........+........
  1       .753                      C         **********C************
  2       .385                  C             ************  C
  3      -.016                 C              *              C
  4      -.404                 C  *************              C
  5      -.628             ***C****************               C
  6      -.687           ***C******************                 C
  7      -.590            C *******************                   C
  8      -.331          C           ***********                     C
  9       .006          C                     *                     C
 10       .314          C                     **********            C
 11       .542         C                      *****************      C
 12       .594        C                       *******************     C
 13       .487       C                        ****************         C
 14       .245      C                         ********                  C
 15      -.008      C                         *                         C
 16      -.245      C                  ********                         C
 17      -.410     C              *************                          C
 18      -.448     C             **************                          C
 19      -.365    C                ************                           C
 20      -.215    C                     *******                           C
 21      -.007    C                           *                           C
 22       .171    C                           ******                      C
 23       .309    C                           **********                  C
 24       .342   C                            ***********                  C
```

C - CONFIDENCE LIMITS (2 X STD. ERR.)
O - COINCIDENCE OF POINTS

```
OPTIONS:

     (1) DIFFERENCE SERIES
     (2) COMPUTE PARTIAL AUTOCORRELATION FUNCTION (PACF)
     (3) CONTINUE TO ESTIMATION MODULE
     (4) RETURN TO CONTROL MODULE

ENTER OPTION (  1 -  4) ? 2

ENTER NO. OF LAGS FOR PACF (  1 - 23) ? 14

LAG                1      2      3      4      5      6      7      8
VALUE            .753  -.421  -.310  -.377  -.112  -.184  -.147  -.007
2 X STD ERR      .320   .320   .320   .320   .320   .320   .320   .320

LAG                9     10     11     12     13     14
VALUE            .055   .019   .093  -.045   .024  -.057
2 X STD ERR      .320   .320   .320   .320   .320   .320
```

```
PLOT PACF (Y/N) ? Y

               PARTIAL AUTOCORRELATION FUNCTION OF SERIES OXYDATA
               --------------------------------------------------


               -1.0      -.67      -.33       0.0       .33       .67       1
 LAG   VALUE     +.........+.........+.........+.........+.........+.........
                                               .
  1       .753                       C         **********C*************
                                               .
  2      -.421                    ***C**********         C
                                               .
  3      -.310                       C**********         C
                                               .
  4      -.377                      *C**********         C
                                               .
  5      -.112                       C      ****         C
                                               .
  6      -.184                       C   *******         C
                                               .
  7      -.147                       C     *****         C
                                               .
  8      -.007                       C         *         C
                                               .
  9       .055                       C         ***       C
                                               .
 10       .019                       C         **        C
                                               .
 11       .093                       C         ****      C
                                               .
 12      -.045                       C        **         C
                                               .
 13       .024                       C         **        C
                                               .
 14      -.087                       C      ****         C

C - CONFIDENCE LIMITS ( 2 X STD. ERR.)
O - COINCIDENCE OF POINTS


OPTIONS:

     (1) DIFFERENCE SERIES
     (2) CONTINUE TO ESTIMATION MODULE
     (3) RETURN TO CONTROL MODULE


ENTER OPTION (  1 -  3) ? 2


****************************************************************************
```

```
IM CPU SECONDS         .21
LA CONNECT HOURS       .2?

                        ESTIMATION MODULE
                        -----------------

IONS:

  (1) ENTER MODEL FROM TERMINAL
  (2) ENTER MODEL FROM A FILE

ER OPTION (  1 -  2) ? 1

                    SPECIFICATION OF MODEL
                    ----------------------

          NOTE: WORKING WITH UNDIFFERENCED SERIES OXYDATA

FERENCE SERIES (Y/N) ? N

ICE PROMPTING SEQUENCE (Y/N) ? Y

ELING OPTIONS:

  (1) SPECIFY AUTOREGRESSIVE MODEL (AR)
  (2) SPECIFY MOVING AVERAGE MODEL (MA)
  (3) EXIT NOVICE PROMPTING SEQUENCE

ER OPTION (  1 -  3) ? 1

                    SPECIFICATION OF AR MODEL
                    -------------------------

ER HIGHEST LAG IN PACF CONTAINING SIGNIFICANT SPIKE (LAG 6 MAX.)

0 -  6) ? 4
```

PARAMETER ESTIMATION

?.back forecast

RINT ITERATIONS (Y/N) ?'N

INITIAL SUM OF SQUARES = 263.425

CONVERGENCE OBTAINED - RELATIVE CHANGE IN SUM OF SQUARES LESS THAN .100000E-0

PARAMETER ESTIMATION HALTED AT ITERATION NO. 3

MODEL SUMMARY OF SERIES OXYDATA

SERIES OXYDATA NOT DIFFERENCED

PARAMETER NUMBER	PRODUCT NUMBER	PARAMETER ORDER	ESTIMATED VALUE	95% CONFIDENCE LEVEL LOWER	UPPER	SIGNIFICANT (Y/N)
1	AR 1	1	.76984	.44923	1.0905	Y
2		2	-.32250E-01	-.46173	.39723	N
3		3	.61770E-01	-.36467	.48821	N
4		4	-.47556	-.79414	-.15698	Y
5	TREND	0	.18061	-.82023	1.1814	N

MEAN OF SERIES = 8.30000

SUM OF SQUARES AFTER REGRESSION = 261.387

COEFFICIENT OF DETERMINATION FOR:

ORIGINAL SERIES .759484

OPTIONS:

(1) CONTINUE TO DIAGNOSTIC CHECK
(2) CONTINUE PARAMETER ESTIMATION
(3) RETURN TO MODEL SPECIFICATION
(4) RETURN TO CONTROL MODULE

ENTER OPTION (1 - 4) ? 1

DIAGNOSTIC CHECK - [illegible]

RESIDUAL SERIES

DATA POINTS = 3[illegible]

MEAN = .243319E-09 VARIANCE = 7.63785
MINIMUM = -5.71174 MAXIMUM = 8.12195

NOTE: MEAN OF RESIDUALS IS ZERO AT THE 95% CONFIDENCE LEVEL.

ER NUMBER OF LAGS FOR AUTOCORRELATION FUNCTION (7 - 48) ? 15

AUTOCORRELATION FUNCTION OF RESIDUALS

	1	2	3	4	5	6	7	8
UE	-.113	-.235	-.215	.165	.145	-.023	-.176	-.052
STD ERR	.338	.342	.360	.375	.383	.389	.389	.398

	9	10	11	12	13	14	15
UE	.066	-.016	.033	.046	.004	-.000	-.006
STD ERR	.399	.400	.400	.403	.403	.403	.403

-SQUARE STATISTIC = 7.37029 WITH 9 DEGREES OF FREEDOM

```
LAG AUTOCORRELATION FUNCTION (Y/N) ? Y

                    -1.0      -.67      -.33      0.0       .33       .67
LAG    VALUE        +.........+.........+.........+.........+.........+........
                                                   .
  1    -.113                            C       ****          C
                                                   .
  2    -.235                            C  ********           C
                                                   .
  3    -.215                           C    *******            C
                                                   .
  4     .165                           C           ******      C
                                                   .
  5     .143                           C           *****       C
                                                   .
  6    -.023                          C          **             C
                                                   .
  7    -.178                          C     ******              C
                                                   .
  8    -.052                          C         ***             C
                                                   .
  9     .046                          C            ***          C
                                                   .
 10    -.016                          C            *            C
                                                   .
 11     .085                          C            ****         C
                                                   .
 12     .046                          C            **           C
                                                   .
 13     .004                          C            *            C
                                                   .
 14    -.000                          C            *            C
                                                   .
 15    -.006                          C            *            C

C - CONFIDENCE LIMITS ( 2 X STD. ERR.)
O - COINCIDENCE OF POINTS
```

... MATRIX FOR ... PARAMETERS (Y/N) ? Y

CORRELATION MATRIX OF PARAMETERS

1	2	3	4	5
1.000	-.716	.015	.395	-.041
-.716	1.000	-.569	.013	-.010
.015	-.569	1.000	-.713	.028
.395	.013	-.713	1.000	-.036
-.041	-.010	.028	-.036	1.000

..E MODEL (Y/N) ? N

..TIONS:

(1) CONTINUE TO FORECASTING MODULE
(2) RETURN TO MODEL SPECIFICATION
(3) RETURN TO CONTROL MODULE

..TER OPTION (1 - 3) ? 1

****

..LR CPU SECONDS .35
..CUM CONNECT HOURS .43

FORECASTING MODULE

```
OPTIONS:

     (1) USE MODEL FROM ESTIMATION
     (2) SPECIFY NEW MODEL

ENTER OPTION (  1 -  2) ? 1

FORECASTS AVAILABLE:

     (1) VARIABLE LEAD TIME
     (2) FIXED LEAD TIME
     (3) BACKWARD

ENTER OPTION (  1 -  3) ? 2

ENTER FORECAST PARAMETERS:

     (1) BACKWARD ORIGIN(  1 - 34) ? 1
     (2) LEAD TIME(  1 -  1) ? 1
     (3) CONF. LEVEL - 1=50%,2=75%,3=90%,4=95%,5=99% - (  1 -  5) ? 2
```

FIXED LEAD TIME FORECAST OF SERIES OXYDATA

75% CONFIDENCE LIMITS

TIME	LEAD TIME	ACTUAL VALUE	FORECAST ERROR	LOWER	FORECASTED VALUE	UPPER	AGREE (Y/N)
39	1	1.7000	1.0073	-2.7018	.69274	4.0873	Y

```
... OF FORECASTING ERRORS ...
... BY THE ESTIMATED STD. DE... OF   2.9...

...                1
...              .3..

... FORECAST(Y/N) ? N

...LE FORECAST (Y/N) ? N

...TIONS:

    (1) PERFORM MORE FORECASTING
    (2) SPECIFY NEW MODEL FOR FORECASTING
    (3) EXIT TO CONTROL MODULE
    (4) EXIT BOX-JENKINS PACKAGE

...TER OPTION (  1 -  4) ? 1

...RECASTS AVAILABLE:

    (1) VARIABLE LEAD TIME
    (2) FIXED LEAD TIME
    (3) BACKWARD

...TER OPTION (  1 -  3) ? 2
```

ENTER FORECAST PARAMETERS:

(1) BACKWARD ORIGIN(1 - 34) ? 34
(2) LEAD TIME(1 - 34) ? 1
(3) CONF. LEVEL - 1=50%,2=75%,3=90%,4=95%,5=99% - (1 - 5) ? 2

FIXED LEAD TIME FORECAST OF SERIES CATLAT

75% CONFIDENCE LIMITS

TIME	LEAD TIME	ACTUAL VALUE	FORECAST ERROR	LOWER	FORECASTED VALUE	UPPER	AGREE (Y/N)
6	1	8.7000	4.1092	1.1962	4.5908	7.9853	N
7	1	6.0000	-5.7117	8.3172	11.712	15.106	N
8	1	9.0000	-.71773	6.3232	9.7177	13.112	Y
9	1	13.100	.51004	9.1954	12.590	15.984	Y
10	1	15.500	3.6790	8.4264	11.821	15.215	N
11	1	14.000	-1.0057	11.611	15.006	18.400	Y
12	1	11.500	-1.1001	9.2056	12.600	15.995	Y
13	1	7.5000	-1.4223	5.5278	8.9223	12.317	Y
14	1	5.7000	1.0104	1.2951	4.6896	8.0841	Y
15	1	.50000	-3.4918	.59728	3.9918	7.3863	N
16	1	1.0000	.11499E-01	-2.4060	.98850	4.3830	Y
17	1	3.0000	-.33217	-.62358E-01	3.3322	6.7267	Y
18	1	3.8000	-1.5905	1.9960	5.3905	8.7851	Y
19	1	8.0000	-.44569	5.0512	8.4457	11.840	Y
20	1	12.000	.46102	8.1445	11.539	14.934	Y
21	1	13.800	.21881	10.187	13.581	16.976	Y
22	1	17.100	2.3831	11.322	14.717	18.111	Y
23	1	14.700	-.74904	12.055	15.449	18.844	Y
24	1	12.500	.79605	8.3094	11.704	15.098	Y
25	1	11.500	2.0645	6.0410	9.4355	12.830	Y
26	1	1.5000	-5.5191	3.6245	7.0191	10.414	N
27	1	1.0000	.64165	-3.0362	.35835	3.7529	Y
28	1	.50000	-.78039	-2.1141	1.2804	4.6749	Y
29	1	2.8000	2.0305	-2.6251	.76946	4.1640	Y
30	1	5.0000	-2.2809	3.8864	7.2809	10.675	Y
31	1	7.3000	-1.8073	5.7128	9.1073	12.502	Y
32	1	9.5000	-1.6868	7.7923	11.187	14.581	Y
33	1	17.300	5.4516	8.4539	11.848	15.243	N
34	1	25.000	8.1220	13.484	16.878	20.273	N
35	1	17.500	-4.0964	18.202	21.596	24.991	N
36	1	13.500	-1.5098	11.615	15.010	18.404	Y
37	1	9.5000	.56140	5.5441	8.9386	12.333	Y
38	1	3.5000	1.6368	-1.5314	1.8632	5.2577	Y
39	1	1.7000	1.0073	-2.7018	.69274	4.0873	Y

[illegible] OF FORECASTING ERRORS [illegible]
[illegible] THE ESTIMATED STD. DEV. OF [illegible]

FCST NO.	1	2	3	4	5	6
SUM ERRS	1.[illegible]9	-.543	-.786	-.[illegible]13	.633	[illegible]
FCST NO.	7	8	9	10	11	12
SUM ERRS	-.803E-01	-.562	-.220	-1.40	-1.40	-1.51
FCST NO.	13	14	15	16	17	18
SUM ERRS	-2.05	-2.20	-2.05	-1.97	-1.16	-1.42
FCST NO.	19	20	21	22	23	24
SUM ERRS	-1.15	-.448	-2.32	-2.10	-2.37	-1.68
FCST NO.	25	26	27	28	29	30
SUM ERRS	-2.45	-3.06	-3.63	-1.79	.963	-.423
FCST NO.	31	32	33	34		
SUM ERRS	-.934	-.744	-.190	.152		

PLOT FORECAST(Y/N) ? Y

ENTER BACKWARD ORIGIN FOR PLOT(0 - 38) ? 25

FIXED LEAD TIME FORECAST PLOT OF SERIES OXYDATA

GRAPH INTERVAL = .824593

```
VALUE -17.0343

14  .                        C   +*  C
15  +                       *   +   C
16  .                   C   O   C
17  .                      C   O   C
18  .                         C * +   C
19  .                            C   O    C
20  +                                C   +*  C
21  .                                   C   O   C
22  .                                    C   +  *C
23  .                                     C  *+   C
24  .                                C   +*  C
25  +                              C   + * C
26  .                        *  C   +   C
27  .                   C   O   C
28  .                    C  *+   C
29  .                   C   +  *C
30  +                           C*  +   C
31  .                             C * +   C
32  .                                C * +   C
33  .                                C    +   C *
34  .                                       C   +   C    *
35  +                                           *C   +   C
36  .                                    C  *+    C
37  .                             C   +*  C
38  .                    C   + *  C
39  .                   C   +*  C

LEGEND : (*) - ACTUAL VALUES
         (+) - FORECASTED VALUES
         (O) - COINCIDENCE OF FORECASTED AND ACTUAL VALUE
         (C) - CONFIDENCE LIMITS
```

```
[illegible] /N, ?

[illegible]

     (1) PERFORM MORE FORECASTING
     (2) SPECIFY NEW MODEL FOR FORECASTING
     (3) EXIT TO CONTROL MODULE
     (4) EXIT BOX-JENKINS PACKAGE

ENTER OPTION (  1 -  4) ? 1

FORECASTS AVAILABLE:

     (1) VARIABLE LEAD TIME
     (2) FIXED LEAD TIME
     (3) BACKWARD

ENTER OPTION (  1 -  3) ? 1

ENTER FORECAST PARAMETERS:

     (1) BACKWARD ORIGIN(  0 - 34) ? 8
     (2) LEAD TIME(  1 - 50) ? 24
     (3) CONF. LEVEL - 1=50%,2=75%,3=90%,4=95%,5=99% - (  1 -  5) ? 2
```

VARIABLE LEAD TIME FORECAST OF SERIES OXYDATA

75% CONFIDENCE LIMITS

TIME	LEAD TIME	ACTUAL VALUE	FORECAST ERROR	LOWER	FORECASTED VALUE	UPPER	[illegible]
32	1	9.5000	-1.6868	7.7925	11.187	14.581	Y
33	2	17.300	4.1530	8.8631	13.147	17.431	
34	3	25.000	11.374	8.9392	13.626	18.314	N
35	4	17.500	4.4213	8.1291	13.079	18.028	Y
36	5	13.500	2.5858	5.9561	10.914	15.872	Y
37	6	9.5000	1.1370	3.2111	8.3630	13.515	Y
38	7	3.5000	-2.7069	.72446	6.2069	11.689	Y
39	8	1.7000	-3.0562	-1.1409	4.7562	10.653	Y
40	9			-1.5194	4.5806	10.661	
41	10			-.55534	5.5723	11.700	
42	11			1.1389	7.2771	13.415	
43	12			2.9759	9.2367	15.497	
44	13			4.3621	10.835	17.308	
45	14			4.9860	11.636	18.286	
46	15			4.7828	11.511	18.240	
47	16			3.8230	10.556	17.290	
48	17			2.3609	9.1146	15.868	
49	18			.80845	7.6469	14.485	
50	19			-.39360	6.5638	13.521	
51	20			-.90227	6.1423	13.187	
52	21			-.62460	6.4478	13.520	
53	22			.25523	7.3277	14.400	
54	23			1.3905	8.4842	15.578	
55	24			2.4136	9.5655	16.717	

PLOT FORECAST(Y/N) ? Y

ENTER BACKWARD ORIGIN FOR PLOT(0 - 38) ? 8

VARIABLE LEAD TIME FORECAST PLOT OF SERIES OXYDATA

GRAPH INTERVAL = .779983

```
31   .                              *
32   .                              C  * +   C
33   .                                C    +     *
34   .                                C     +     C       *
35   .                               C     +     *C
36   .                            C     +   *  C
37   .                         C     + *    C
38   .                     C   *  +      C
39   .                   C   *   +      C
40   +                  C       +       C
41   .                    C       +      C
42   .                      C       +       C
43   .                        C       +       C
44   .                          C       +        C
45   +                           C       +        C
46   .                           C       +        C
47   .                         C        +        C
48   .                       C        +        C
49   .                     C        +        C
50   +                    C        +        C
51   .                   C        +        C
52   .                    C        +        C
53   .                     C        +        C
54   .                      C        +        C
55   +                        C        +        C
```

LEGEND : (*) - ACTUAL VALUES
(+) - FORECASTED VALUES
(O) - COINCIDENCE OF FORECASTED AND ACTUAL VALUE
(C) - CONFIDENCE LIMITS

```
FILE FORECAST (Y/N) ? N

OPTIONS:

     (1) PERFORM MORE FORECASTING
     (2) SPECIFY NEW MODEL FOR FORECASTING
     (3) EXIT TO CONTROL MODULE
     (4) EXIT BOX-JENKINS PACKAGE

ENTER OPTION (  1 -  4) ? 4


ACCUM CPU SECONDS       .55
ACCUM CONNECT HOURS     .78

****************************************************************************************
*RDY*
ACT;T
CT = 00.85    SU-B =      17.3
*RDY*
```

CT ≈ 22/hr at service A
cpu ≈ 15¢

Deer Kill Simulation Model

The following are excerpts from "Application of Leslie Matrices to Population Dynamics of Elk" (Fosdick, G.E., Colorado State University, Ft. Collins, CO, 1974).

The deer kill simulation model may be used to estimate population growth and deer road kill according to input paramenters such as traffic counts, previous road kills, hunting regulations, and initial populations.

III. RESULTS

A. Simulation of the System

The population dynamics of elk were simulated for both exploited and unexploited cases on the CDC 6400 digital computer utilizing the two-sex Leslie matrix model. Specific inputs for the Leslie matrix, M, are indicated on Figure 3 for both the 10 X 10 two-year age-class model and the 14 X 14 one-year age-class model.

Three hunting matrix alternatives are allowed:

a. KHUNT = 0 No hunting (KHUNT is called the hunting matrix indicator).

b. KHUNT = 1 Two distinct hunting matrices are entered in alternative years, e.g. bulls-only in odd years and bulls + cows in even years.

c. KHUNT = 2 Any one type hunting matrix is entered in arbitrary years as indicated by K1 (KOUNT) equal to 0 or 1 where KOUNT is the generation number from 1 to 25. A 1 indicates hunting in that generation; a 0 indicates no hunting.

B. Presentation of the Results

The run program is shown on Figure 5 and indicates the size of the M matrix, the initial population distribution (uniform or stable), KHUNT, K1 (KOUNT), and θ = the fraction of each class surviving hunting. An identical value of θ was used for all age classes for all runs made.

Nomenclature for the computer program is as follows:

Definition	Text Description	Computer Program
Leslie Matrix	$\underline{M}$	A(I, J)
Initial Pop. Vector	$\underline{n}_0$	POPZ(I, J)
Pop. Vector	$\underline{n}$	POPT(I, J)
Time Step	$\underline{t}$	KOUNT
Hunting Matrix Indicator	KHUNT	KHUNT
First Type Hunting Matrix	θ	AHN1(I, J)
Sec. Type Hunting Matrix	θ	AHN2(I, J)

FIGURE 3

INITIAL LESLIE MATRIX

0.00	.12	0.00	.44	0.00	.48	0.00	.47	0.00	.36
0.00	.12	0.00	.44	0.00	.48	0.00	.47	0.00	.35
.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	.75	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	.67	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	.63	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	.40	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	.42	0.00	0.00

INITIAL POPULATION DISTRIBUTION VECTOR

100.00 100.00 100.00 100.00 100.00 100.00 100.00 100.00 100.00 100.00

POPULATION SUM = 1000.00

INITIAL LESLIE MATRIX

.00	0.00	0.00	.21	0.00	.43	0.00	.45	0.00	.47	0.00	.48	0.00	.43
.00	0.00	0.00	.21	0.00	.43	0.00	.45	0.00	.47	0.00	.48	0.00	.43
.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.00	.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.00	0.00	0.00	0.00	.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.00	0.00	0.00	0.00	0.00	.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.00	0.00	0.00	0.00	0.00	0.00	.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.00	0.00	0.00	0.00	0.00	0.00	0.00	.73	0.00	0.00	0.00	0.00	0.00	0.00
.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.75	0.00	0.00	0.00	0.00	0.00
.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.67	0.00	0.00	0.00	0.00
.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.60	0.00	0.00	0.00
.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.59	0.00	0.00

NITIAL POPULATION DISTRIBUTION VECTOR

72.0 72.0 72.0 72.0 72.0 72.0 72.0 72.0 72.0 72.0 72.0 72.0 72.0

POPULATION SUM = 1008.00

Figure 5 Run Program

Run No.	Date	Init.Pop.Distrib.	Harvest	Matrix Size
1	1/25/74	100,.......,100	KHUNT=0	10 x 10
2	1/25/74	100,.......,100	KHUNT=2 θ=0.5*	10 x 10
3	1/30/74	72,........,72	KHUNT=2 θ=0.9*	14 x 14
4	1/30/74	72,........,72	KHUNT=2 θ=0.1*	14 x 14
5	1/30/74	72,........,72	KHUNT=0	14 x 14
6	2/1/74	Stable Dist.	KHUNT=0	14 x 14
7	2/1/74	Stable Dist.	KHUNT=2 θ=0.97	14 x 14
8	2/13/74	Stable Dist.	KHUNT=2 θ=0.975	14 x 14

* Hunting only in even numbered generations

Note: When KHUNT = 1, both AHN1 and AHN2 are entered in alternative years; when KHUNT = 2 only AHN2 is entered when K1 (KOUNT) = 1.

The computer listing and outputs for runs 1 to 8 are presented in the Appendix.

Typical results in tabular form are given on Figure 6. Figure 6 gives the population distribution by sex and age class and total population for the initial (first) generation and for generations 24 and 25 for the following cases:

Run	Initial Population Distribution	θ	Hunting
3	Uniform	.90	In even years
5	Uniform	1.0	NONE
6	Stable	1.0	NONE
7	Stable	.97	Every Year
8	Stable	.975	Every Year

Initial populations were approximately 1000 animals. (For the uniform cases with 72 animals per class, the total was 1008). Using fractional animals for the initial stable distribution the initial value of 1000 animals was achieved.

The stable age distribution was calculated from run 5, an initial uniform distribution; also calculated is the allowable harvest for a stable population size, as follows:

26 generations were computed per run and

$$\lambda = \frac{n_{26}}{n_{25}} = \frac{\text{Total pop. in 26th generation}}{\text{Total pop. in 25th generation}} = \frac{1939}{1891} = 1.025$$

This value of λ is the principal eigenvalue. Therefore the approximate harvest for zero growth (i.e. a stable population) is

$$\text{Harvest (H)} \cong \frac{\lambda - 1}{\lambda} = \frac{1.025 - 1}{1.025} = .0244$$

or the fraction surviving harvest (θ) is

$$\theta = 1 - H = 1 - .0244 = .9756$$

A value of .975 was used in run 8 for which the initial population of 1000 decreased to 997 after 25 generations.

After 25 generations the total population decreased from 1000 to 997 indicating that the method holds. Furthermore the calculated stable age distribution which was inputted to run 8 was maintained for 25 generations.

Figure 6 Typical Results

Run & θ	Generation	Male/Female	Population by Age Class 1	2	3	4	5	6	7	Tot M+F
5/1	1	M	72	72	72	72	72	72	72	
(U)	24	M	215	174	166	159	152	111	65	
	25	M	221	179	171	163	156	114	67	
	1	F	72	72	72	72	72	72	72	1008
	24	F	215	178	143	109	77	51	29	1844
	25	F	221	183	146	111	79	52	30	1891
6/1	1	M	117	95	90	86	83	60	34	
(S)	24	M	208	169	161	154	147	108	63	
	25	M	214	173	165	158	151	110	65	
	1	F	117	97	78	59	42	27	15	1000
	24	F	208	173	138	105	75	49	28	1786
	25	F	214	177	142	108	77	50	29	1831
7/.97	1	M	117	95	90	86	83	60	34	
(S)	24	M	103	84	80	76	73	53	31	
	25	M	103	83	80	76	73	53	31	
	1	F	117	97	78	59	42	27	15	1000
	24	F	103	86	69	52	37	24	14	866
	25	F	103	85	68	52	37	24	14	881
8/.975 (S)	1	M	117	95	90	86	83	60	34	
	24	M	116	94	90	86	82	60	35	
	25	M	116	94	90	86	82	60	35	
	1	F	117	97	78	59	42	27	15	1000
	24	F	116	96	77	59	42	27	16	997
	25	F	116	96	77	59	42	27	16	997
3/.90	1	M	72	72	72	72	72	72	72	
	24	M	61	49	47	45	43	31	18	
	25	M	62	50	48	46	44	32	19	
	1	F	72	72	72	72	72	72	72	1008
	24	F	61	50	40	31	22	14	8	521
	25	F	62	52	41	31	22	15	8	534

Note: In column 1, (U)= Uniform initial age distribution
(S)= Stable " " "

By comparing runs 7 and 8 for which the θ's were respectively .970 and .975, the sensitivity of population to hunting pressure can be obtained. The .97 value caused the population to decrease from 1000 initially to 881 in 25 generations or - 4.75 animals per generation whereas .975 caused a decrease to 997 in 25 generations or -0.12 animals/generation or a $\Delta\theta$ of -0.005 caused a decrease of -4.63 animals/generation for an initial herd size of 1000 animals.